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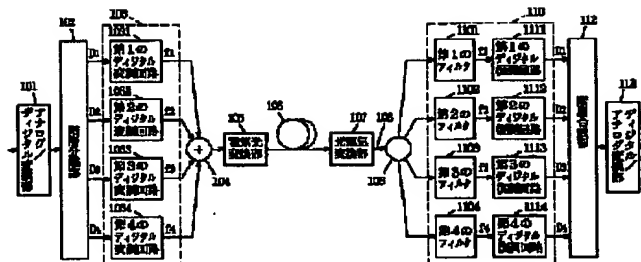
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TITLE : OPTICAL TRANSMISSION EQUIPMENT  
AND OPTICAL TRANSMISSION  
SYSTEM USING THE SAME



**ABSTRACT :** PROBLEM TO BE SOLVED: To make transmission quality uniform at each channel by performing A/D conversion and hierarchical separation to a transmission analog signal and performing batch optical transmission by modulating and multiplexing the carrier wave of a correspondent frequency for each hierarchy.

**SOLUTION:** A digital electric signal passed through an A/D converter 101 is divided into plural hierarchies corresponding to the degree of importance consisting of source data by a hierarchical separation part 102 and modulated by 1st-4th digital modulation circuits 1031-1034 at a modulation part 103 for modulating the modulating carrier wave of a frequency corresponding to each hierarchy by a hierarchical signal. This modulated signal is passed through a multiplexer part 104 and an electric/optic converting part 105 and a batch signal is transmitted. In this case, the carrier signal of a low frequency is modulated by the modulation part 103 corresponding to the degree of importance consisting of a transmission signal and the transmission quality can be made uniform at low cost for each channel having the different levels of waveform degradation and distortion corresponding to bands.

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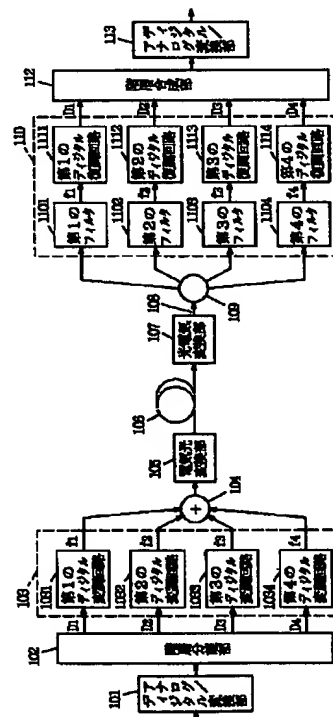
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(54) 【発明の名称】 光送信装置およびそれを用いた光伝送システム

(57) 【要約】

【課題】 アナログSCM伝送技術を用いて、複数のデジタル変調信号を一括光伝送するシステムでは、帯域によって伝送信号の波形劣化の程度または歪みの大きさが異なり、各チャンネルの伝送品質に差異が生じるという問題があった。

【解決手段】 伝送すべきアナログ信号は、アナログ／デジタル変換部101でデジタル信号に変換された後、階層分離部102で元のアナログ信号を構成する上での重要度に応じて、複数グループのデジタル情報に分割される。変調部103は、各グループに個別的に割り当てられ互いに異なる周波数の搬送波を、該デジタル情報でデジタル変調する。多重部104は、全てのデジタル変調信号を周波数多重して一括光伝送する。この場合、重要なデジタル情報を司る搬送波ほど低周波側に設定し、重要度の低いデジタル情報を司る搬送波ほど高周波側に設定する。



**【特許請求の範囲】**

**【請求項1】** 周波数多重されたデジタル変調信号を光伝送するシステムであって、与えられたデジタル信号を、所定の階層化方式に従い、元のデータを構成する上での重要度に応じて、 $n$  ( $n$ は、2以上の自然数)個の階層に分割し、重要度の高いものから順番に並べられた第1～第 $n$ のデジタル情報として出力する階層分離部と、前記第1～第 $n$ のデジタル情報に個別的に割り当てられた互いに周波数の異なる第1～第 $n$ の搬送波を、当該デジタル情報でデジタル変調して、第1～第 $n$ のデジタル変調信号を出力する変調部と、前記変調部から出力された第1～第 $n$ のデジタル変調信号を周波数多重する多重部と、前記多重部から出力された電気信号を光信号に変換する電気光変換部と、前記電気光変換部から出力された光信号を伝送する光伝送路と、前記光伝送路によって伝送された光信号を電気信号に再変換する光電気変換部と、前記光電気変換部から出力された電気信号を伝送する伝送路と、前記伝送路によって伝送された電気信号を $m$  ( $m$ は、 $1 \leq m \leq n$ の自然数)個の電気信号に分岐する分岐部と、前記分岐部から出力された $m$ 個の電気信号をそれぞれ復調して、前記第1～第 $n$ のデジタル情報の中から選択された第1～第 $m$ のデジタル情報を出力する復調部と、前記第1～第 $m$ のデジタル情報を入力し、前記所定の階層化方式と逆の過程に従ってデジタル信号を合成して出力する階層合成部とを備える、光伝送システム。

**【請求項2】**  $n > m$ の場合、前記復調部は、前記分岐部から出力された $m$ 個の電気信号をそれぞれ復調して、前記第1～第 $n$ のデジタル情報の内、重要度の高いものから順番に選択された第1～第 $m$ のデジタル情報を出力することを特徴とする、請求項1に記載の光伝送システム。

**【請求項3】** 前記光伝送路の全伝送帯域において、前記第1～第 $n$ の搬送波は、重要度の高いデジタル情報に割り当てられる搬送波ほど、より伝送特性の良好な帯域に配置され、重要度の低いデジタル情報に割り当てられる搬送波ほど、より伝送特性の悪い帯域に配置されることを特徴とする、請求項1に記載の光伝送システム。

**【請求項4】** 前記デジタル信号は、 $w$  ( $w$ は、 $n$ 以上の自然数)ビットを有するデジタル信号であり、前記階層分離部は、前記 $w$ ビットのデジタル信号を、最上位ビットから最下位ビットまで順番に、1ビット以上毎に第1～第 $n$ のデジタル情報に分割し、前記光伝送路の全伝送帯域において、前記第1～第 $n$ の

搬送波は、最上位ビットに近いビットが属するデジタル情報に割り当てられる搬送波ほど、より伝送特性の良好な帯域に配置され、最下位ビットに近いビットが属するデジタル情報に割り当てられる搬送波ほど、より伝送特性の悪い帯域に配置されることを特徴とする、請求項3に記載の光伝送システム。

**【請求項5】** 前記階層分離部は、前記デジタル信号に対し、所定の時間/周波数変換を施し、直流成分から最高周波成分まで順番に、第1～第 $n$ のデジタル情報に分割し、前記光伝送路の全伝送帯域において、前記第1～第 $n$ の搬送波は、直流成分に近い成分が属するデジタル情報に割り当てられる搬送波ほど、より伝送特性の良好な帯域に配置され、最高周波成分に近い成分が属するデジタル情報に割り当てられる搬送波ほど、より伝送特性の悪い帯域に配置されることを特徴とする、請求項3に記載の光伝送システム。

**【請求項6】** 前記階層分離部は、前記デジタル信号に対し、前記所定の時間/周波数変換として、フーリエ変換を施すことを特徴とする、請求項5に記載の光伝送システム。

**【請求項7】** 前記階層分離部は、前記デジタル信号に対し、前記所定の時間/周波数変換として、離散コサイン変換(DCT)を施すことを特徴とする、請求項5に記載の光伝送システム。

**【請求項8】** 前記光伝送路の全伝送帯域において、より伝送特性の良好な帯域は、より低周波数域であり、より伝送特性の良好でない前記帯域は、より高周波数域であることを特徴とする、請求項3～7のいずれかに記載の光伝送システム。

**【請求項9】**  $p$ チャンネル( $p$ は、2以上の自然数)のデジタル信号に対応して、前記階層分離部と、前記変調部と、前記復調部と、前記階層合成部とが $p$ 組設けられており、

前記多重部は、前記 $p$ 組の変調部から出力される全デジタル変調信号を周波数多重し、前記分岐部は、前記伝送路によって伝送された電気信号を分岐して、前記 $p$ 組の復調部に入力し、それによって前記 $p$ チャンネルのデジタル信号を周波数多重して一括光伝送することを特徴とする、請求項1に記載の光伝送システム。

**【請求項10】** 前記光伝送路途上に配置され、光信号を $q$  ( $q$ は、2以上の自然数)個に分岐する光分岐部をさらに備え、

前記光電気変換部と、前記伝送路と、前記分岐部と、前記 $p$ 組の復調部と、前記 $p$ 組の階層合成部とで構成される光受信セットが、前記光分岐部によって分岐された $q$ 個の光信号に対応して、 $q$ セット設けられていることを特徴とする、請求項9に記載の光伝送システム。

**【請求項11】** 前記 $q$ セットの光受信セットの内、少

なくとも一部のセットにおいて、 $n > m$ の条件が成立することを特徴とする、請求項9に記載の光伝送システム。

【請求項12】 前記光電気変換部からの出力信号を $t$  ( $t$ は、2以上の自然数)個に分岐する電気分配部をさらに備え、

前記伝送路と、前記分岐部と、前記 $p$ 組の復調部と、前記 $p$ 組の階層合成部とで構成される光受信セットが、前記光分岐部によって分岐された $t$ 個の電気信号に対応して、 $t$ セット設けられていることを特徴とする、請求項9に記載の光伝送システム。

【請求項13】 前記 $t$ セットの光受信セットの内、少なくとも一部のセットにおいて、 $n > m$ の条件が成立することを特徴とする、請求項12に記載の光伝送システム。

【請求項14】 前記光伝送路の全伝送帯域を低域から高域にかけて第1～第 $n$ の情報伝送帯域に分割し、各帯域内には、互いに異なる周波数の $p$ 個の搬送波を設定し、前記 $p$ チャンネルのデジタル信号のそれぞれに対して割り当てられる前記第1～第 $n$ の搬送波は、第1～第 $n$ の情報伝送帯域から1つずつピックアップされることを特徴とする、請求項9～13のいずれかに記載の光伝送システム。

【請求項15】 アナログ信号をデジタル信号に変換して前記階層変換部に入力するアナログ/デジタル変換部と、前記階層合成部から出力されたデジタル信号をアナログ信号に再変換するデジタル/アナログ変換部とをさらに備える、請求項1～14のいずれかに記載の光伝送システム。

【請求項16】 周波数多重されたデジタル変調信号を光信号に変換して光伝送路上に送信する光送信装置であって、与えられたデジタル信号を、所定の階層化方式に従い、元のデータを構成する上での重要度に応じて、 $n$  ( $n$ は、2以上の自然数)個の階層に分割し、重要度の高いものから順番に並べられた第1～第 $n$ のデジタル情報として出力する階層分離部と、前記第1～第 $n$ のデジタル情報に個別的に割り当てられた互いに周波数の異なる第1～第 $n$ の搬送波を、当該デジタル情報でデジタル変調して、第1～第 $n$ のデジタル変調信号を出力する変調部と、前記変調部から出力された第1～第 $n$ のデジタル変調信号を周波数多重する多重部と、前記多重部から出力された電気信号を光信号に変換して前記光伝送路上に送出する電気光変換部とを備える、光送信装置。

【発明の詳細な説明】

【0001】

【発明の実施の形態】本発明は、光伝送システムに関

し、より特定的には、周波数多重されたデジタル変調信号を光伝送するシステムに関する。

【0002】

【従来の技術】図9は、従来の光伝送システムの第1の例を示した図である。図9において、この光伝送システムは、アナログ/デジタル変換部901と、デジタル変調回路903と、電気光変換部905と、光伝送路906と、光電気変換部907と、伝送路908と、復調部9100と、デジタル/アナログ変換部913とを備えている。なお、復調部9100は、フィルタ910と、デジタル復調回路911とを含む。

【0003】次に、図9に示す従来の光伝送システムの動作について説明する。アナログ/デジタル変換部901は、例えば映像信号のようなアナログ信号を、サンプリングおよび量子化してデジタル信号に変換する。デジタル変調回路903は、所定の周波数 $f_0$ の搬送波を用いて、所定のデジタル変調方式により、上記デジタル信号をデジタル変調信号に変換し、出力する。このデジタル変調信号は、電気光変換部905において光信号に変換され、光伝送路906によって伝送された後、光電気変換部907において電気信号に再変換される。復調部9100では、フィルタ910を透過した該周波数 $f_0$ の上記デジタル変調信号を、デジタル復調回路911がデジタル信号に変換する。デジタル/アナログ変換部913は、当該デジタル信号をアナログ信号に再変換する。上記所定のデジタル変調方式としては、例えば16QAM変調方式があり、この場合、一般に数10Mbpsの伝送レートを確保することが可能である。

【0004】図10は、従来の光伝送システムの第2の例を示した図である。図10において、この光伝送システムは、アナログ/デジタル変換部901と、分割部1002と、変調部1003と、多重部1004と、電気光変換部905と、光伝送路906と、光電気変換部907と、伝送路908と、分岐部1009と、復調部1010と、合成部1012と、デジタル/アナログ変換部913とを含む。また、変調部1003は、第1のデジタル変調回路10031と、第2のデジタル変調回路10032とを含む。また、復調部1010は、第1のフィルタ10101と、第2のフィルタ10102と、第1のデジタル復調回路10111と、第2のデジタル復調回路10112とを含む。

【0005】次に、図10に示す従来の光伝送システムの動作について説明する。本例は、上述の第1の従来例よりも、伝送レートが高い場合の構成を示し、1つの信号を伝送するために、予め定められた互いに異なる2つの周波数 $f_1$ 、 $f_2$ の搬送波を使用する。すなわち、分割部1002は、アナログ/デジタル変換後のデジタル信号を、所定の分割法に従って、2つのデジタル情報グループ(第1のデジタル情報 $J_1$ および第2の

デジタル情報 $J_2$ )に分割する。そして、これら分割された2つのデジタル情報を、変調部1003内の第1のデジタル変調回路10031および第2の変調回路10032が、各々独立の2つの搬送波(周波数 $f_1$ ,  $f_2$ )を用いてデジタル変調信号に変換し、多重部1004が周波数多重して1信号とする。

【0006】電気光変換部905、光伝送路906、光電気変換部907、伝送路908を介して伝送された信号は、分岐部1009において2分岐された後、復調部1010内の第1のフィルタ10101および第2のフィルタ10102に入力される。第1のデジタル復調回路10111は、第1のフィルタ10101を透過した第1のデジタル変調信号(周波数 $f_1$ )を、第1のデジタル情報 $J_1$ に復調する。また、第2のデジタル復調回路10112は、第2のフィルタ10102を透過した第2のデジタル変調信号(周波数 $f_2$ )を、第2のデジタル情報 $J_2$ に復調する。合成部1012は、これら第1および第2のデジタル情報 $J_1$ および $J_2$ を、上記分割部1002における上記所定の分割法の逆過程に従って合成し、デジタル信号を再生する。ここで、所定の分割法としては、例えば、1サンプルおきに2グループに分ける方法などがある。第1の従来例において説明したように、デジタル変調信号は、1搬送波で伝送できる容量に限りがある。そのため、本例では、伝送すべきデジタル信号を複数(図10では2つ)の情報グループに分割し、各々を独立の搬送波を用いてデジタル変調信号に変換し、これを周波数多重して一括伝送することにより、より高い(第1の従来例の2倍の)伝送レートを確保している。

【0007】図11は、従来の光伝送システムの第3の例を示した図である。図11において、この光伝送システムは、第1～第3のアナログ/デジタル変換部11011～11013と、分割部1102と、第1～第3の変調部11031～11033と、チャンネル多重部1104と、電気光変換部905と、光伝送路906と、光電気変換部907と、伝送路908と、チャンネル分岐部1109と、第1～第3の復調部11101～11103と、合成部1112と、第1～第3のデジタル/アナログ変換部11131～11133とを備えている。

【0008】次に、図11に示す従来の光伝送システムの動作について説明する。前述の第1および第2の従来例が1チャンネルの伝送システムであるのに対し、本従来例は、複数チャンネル(図11では3チャンネル)の伝送に対応した構成となっている。すなわち、本従来例では、3チャンネルの信号 $C_1$ ,  $C_2$ ,  $C_3$ に対して、例えば図12に示すように、予め割り当てられた互いに異なる周波数 $f_1$ ,  $f_{21}$ ,  $f_{22}$ ,  $f_3$ の搬送波を用いてデジタル変調を施し、これを周波数多重して一括光伝送する。そのために、本従来例は、3つの伝送信号 $C$

$1$ ,  $C_2$ ,  $C_3$ の各々に対して、アナログ/デジタル変換部、変調部、復調部、デジタル/アナログ変換部を備え、チャンネル多重部1104は、全ての変調部11031～11033から出力されるデジタル変調信号を周波数多重する。チャンネル分岐部1109は、電気光変換部905～伝送路908を介して光伝送された信号を分岐して、全ての復調部11101～11103に入力する。なお、図11では、第2チャンネルの信号 $C_2$ のみ高い伝送レートを要するものとし、分割部1102および合成部1112を備え、2つの搬送波(周波数 $f_{21}$ ,  $f_{22}$ )を用いて伝送する。各構成要素の詳しい動作は、第1および第2の従来例と同様であるため、その詳細な説明を省略する。

【0009】上記のように、複数の搬送波を用いて周波数多重信号を光伝送するアナログSCM(Sub-Carrier Multiplex)伝送技術を用いたシステムは、容易に高ビットレート・多チャンネルの情報を伝送できるシステムとして有効なものである。しかしながら、一般に伝送系(電気光変換部～光伝送路～光電気変換部～伝送路)は、周波数特性を有し、全伝送帯域に亘って等しく一様な伝送特性を得ることは困難である。例えば、電気光変換部に用いられる直接変調用光源(半導体レーザ)は、その緩和振動周波数の影響のため、高周波域程、電気光変換時の非線形性による波形歪が大きくなるという特性を持つ。このため、搬送波周波数の高いデジタル変調信号の波形劣化は、搬送波周波数の低いデジタル変調信号の波形劣化に比べて大きくなり、BER(符号誤り率)などの伝送品質が悪化するという欠点を有している。また、伝送チャンネル数が大きい場合、2次歪みは伝送帯域の真ん中付近で、また3次歪みは伝送帯域の上下で大きくなるという性質を有している。

#### 【0010】

【発明が解決しようとする課題】上述のように、アナログSCM伝送技術を用いて、複数のデジタル変調信号を伝送する従来の光伝送システムでは、帯域によって伝送信号の波形劣化の程度あるいは歪みの大きさが異なり、各チャンネルの伝送品質に差異が生じるという問題があった。

【0011】なお、上記のような問題は、アナログ信号をデジタル信号に変換して伝送する場合に限らず、デジタルデータを多重化して光伝送する場合にも生じる。

【0012】それ故に、本発明の目的は、全伝送帯域内における伝送特性の不揃いが、受信側で再生された情報に与える影響を最小限に軽減し、あるいはチャンネル間の受信品質の差異を回避し得る光伝送システムおよび光送信装置を提供することである。

【0013】本発明の他の目的は、全てのチャンネルの情報を送信または受信することができない場合であって

も、受信側で再生される信号の品質をできるだけ良好に保つことができる光伝送システムおよび光送信装置を提供することである。

【0014】

【課題を解決するための手段および発明の効果】第1の発明は、周波数多重されたデジタル変調信号を光伝送するシステムであって、与えられたデジタル信号を、所定の階層化方式に従い、元のデータを構成する上での重要度に応じて、 $n$  ( $n$ は、2以上の自然数)個の階層に分割し、重要度の高いものから順番に並べられた第1～第 $n$ のデジタル情報として出力する階層分離部と、第1～第 $n$ のデジタル情報に個別的に割り当てられた互いに周波数の異なる第1～第 $n$ の搬送波を、当該デジタル情報でデジタル変調して、第1～第 $n$ のデジタル変調信号を出力する変調部と、変調部から出力された第1～第 $n$ のデジタル変調信号を周波数多重する多重部と、多重部から出力された電気信号を光信号に変換する電気光変換部と、電気光変換部から出力された光信号を伝送する光伝送路と、光伝送路によって伝送された光信号を電気信号に再変換する光電気変換部と、光電気変換部から出力された電気信号を伝送する伝送路と、伝送路によって伝送された電気信号を $m$  ( $m$ は、 $1 \leq m \leq n$ の自然数)個の電気信号に分岐する分岐部と、分岐部から出力された $m$ 個の電気信号をそれぞれ復調して、第1～第 $n$ のデジタル情報の中から選択された第1～第 $m$ のデジタル情報を出力する復調部と、第1～第 $m$ のデジタル情報を入力し、所定の階層化方式と逆の過程に従ってデジタル信号を合成して出力する階層合成部とを備えている。

【0015】上記のように、第1の発明では、伝送すべきデジタル信号を、元のデータを構成する上での重要度に応じて、複数階層のデジタル情報に分割し、各階層毎に割り当てられた互いに異なる周波数の搬送波を、当該デジタル情報でデジタル変調し、全てのデジタル変調信号を周波数多重して一括光伝送する。また、光伝送後の再変換された電気信号に対して、各デジタル変調信号を復調し、各グループのデジタル情報を合成して、元のデジタル信号を再生する。

【0016】従って、第1の発明によれば、伝送信号を構成する上での重要度に応じて、伝送情報に対して種々の操作ないし伝送制御が可能となる。その結果、高品質、低コストで、かつ発展性に優れた光伝送システムを実現することができる。

【0017】第2の発明は、第1の発明において、 $n > m$ の場合、復調部は、分岐部から出力された $m$ 個の電気信号をそれぞれ復調して、第1～第 $n$ のデジタル情報の内、重要度の高いものから順番に選択された第1～第 $m$ のデジタル情報を出力することを特徴とする。

【0018】光伝送路の容量が小さい場合や、受信器の能力が低い場合、全階層のデジタル情報を伝送あるいは

は受信できない場合が生じる。このような場合、第2の発明では、重要度の高い情報を優先的に伝送または受信することにより、再生されたデータに生じる影響を最小限に抑えるようにしている。

【0019】第3の発明は、第1の発明において、光伝送路の全伝送帯域において、第1～第 $n$ の搬送波は、重要度の高いデジタル情報に割り当てられる搬送波ほど、より伝送特性の良好な帯域に配置され、重要度の低いデジタル情報に割り当てられる搬送波ほど、より伝送特性の悪い帯域に配置されることを特徴とする。

【0020】前述したように、周波数多重された信号を光伝送路を用いて伝送する場合、使用する帯域によって伝送信号の波形劣化の程度あるいは歪みの大きさが異なる。そこで、第3の発明では、重要度の高い階層情報は伝送特性の良好な帯域で伝送し、重要度の低い階層情報は伝送特性の悪い帯域で伝送することにより、伝送時に発生する劣化や歪みが、受信側で再生されたデータに与える影響を最小限に抑えるようにしている。これによって、高品質な伝送が可能となる。

【0021】第4の発明は、第3の発明において、デジタル信号は、 $w$  ( $w$ は、 $n$ 以上の自然数)ビットを有するデジタル信号であり、階層分離部は、 $w$ ビットのデジタル信号を、最上位ビットから最下位ビットまで順番に、1ビット以上毎に第1～第 $n$ のデジタル情報に分割し、光伝送路の全伝送帯域において、第1～第 $n$ の搬送波は、最上位ビットに近いビットが属するデジタル情報に割り当てられる搬送波ほど、より伝送特性の良好な帯域に配置され、最下位ビットに近いビットが属するデジタル情報に割り当てられる搬送波ほど、より伝送特性の悪い帯域に配置されることを特徴とする。

【0022】上記のように、第4の発明では、複数ビットを有するデジタル信号を、1ビット以上毎に分割して、第1～第 $n$ のデジタル情報に階層化するようにしている。そして、データを構成する上で重要度が高い上位ビットのデジタル情報は伝送特性の良好な帯域で伝送し、データを構成する上で重要度が低い下位ビットのデジタル情報は伝送特性の悪い帯域で伝送するようにしている。これによって、高品質な伝送が可能となる。

【0023】第5の発明は、第3の発明において、階層分離部は、デジタル信号に対し、所定の時間/周波数変換を施し、直流成分から最高周波成分まで順番に、第1～第 $n$ のデジタル情報に分割し、光伝送路の全伝送帯域において、第1～第 $n$ の搬送波は、直流成分に近い成分が属するデジタル情報に割り当てられる搬送波ほど、より伝送特性の良好な帯域に配置され、最高周波成分に近い成分が属するデジタル情報に割り当てられる搬送波ほど、より伝送特性の悪い帯域に配置されることを特徴とする。

【0024】上記のように、第5の発明では、デジタル信号に対し、所定の時間/周波数変換を施すことによ

り、直流成分から最高周波成分まで順番に、第1～第 $n$ のデジタル情報に分割するようにしている。そして、データを構成する上で重要度が高いデジタル情報、すなわち直流成分に近い成分が属するデジタル情報は伝送特性の良好な帯域で伝送し、データを構成する上で重要度が低いデジタル情報、すなわち最高周波成分に近い成分が属するデジタル情報は伝送特性の悪い帯域で伝送するようにしている。これによって、高品質な伝送が可能となる。

【0025】第6の発明は、第5の発明において、階層分離部は、デジタル信号に対し、所定の時間/周波数変換として、フーリエ変換を施すことを特徴とする。

【0026】第7の発明は、第5の発明において、階層分離部は、デジタル信号に対し、所定の時間/周波数変換として、離散コサイン変換(DCT)を施すことを特徴とする。

【0027】第8の発明は、第3～7のいずれかの発明において、光伝送路の全伝送帯域において、より伝送特性の良好な帯域は、より低周波数域であり、より伝送特性の良好でない帯域は、より高周波数域であることを特徴とする。

【0028】前述したように、一般的に光伝送システムにおいて、搬送波周波数の高いデジタル変調信号の波形劣化は大きくなる。そこで、第8の発明では、重要度の高いデジタル情報を伝送する帯域として低周波数域を用い、重要度の低いデジタル情報を伝送する帯域として高周波数域を用いるようにしている。

【0029】なお、特定の次数の歪みについての波形劣化を問題とする場合は、伝送特性の良好でない帯域が高域に分布しているとは限らないので、重要度の低いデジタル情報を伝送するために、高域以外の他の帯域が用いられる場合もある。例えば、3次歪みは、全伝送帯域中の中間帯域で大きくなるので、3次歪みによる波形劣化を問題とする場合、重要度の低いデジタル情報は、中間帯域を用いて伝送される。また、2次歪みは、全伝送帯域中の高域および低域で大きくなるので、2次歪みによる波形劣化を問題とする場合、重要度の低いデジタル情報は、高域または低域を用いて伝送される。

【0030】第9の発明は、第1の発明において、 $p$ チャンネル( $p$ は、2以上の自然数)のデジタル信号に対応して、階層分離部と、変調部と、復調部と、階層合成部とが $p$ 組設けられており、多重部は、 $p$ 組の変調部から出力される全デジタル変調信号を周波数多重し、分岐部は、伝送路によって伝送された電気信号を分岐して、 $p$ 組の復調部に入力し、それによって $p$ チャンネルのデジタル信号を周波数多重して一括光伝送することを特徴とする。

【0031】上記のように、第9の発明では、階層分離部と、変調部と、復調部と、階層合成部とを $p$ 組設けることにより、 $p$ チャンネルのデジタル信号を周波数多

重して一括光伝送するようにしている。これによって、伝送能力がさらに増大する。

【0032】第10の発明は、第9の発明において、光伝送路途上に配置され、光信号を $q$ ( $q$ は、2以上の自然数)個に分岐する光分岐部をさらに備え、光電気変換部と、伝送路と、分岐部と、 $p$ 組の復調部と、 $p$ 組の階層合成部とで構成される光受信セットが、光分岐部によって分岐された $q$ 個の光信号に対応して、 $q$ セット設けられていることを特徴とする。

【0033】上記のように、第10の発明では、光伝送路途上の光信号を $q$ 個の光信号に分岐することにより、複数の受信器に同時に分配することを可能にしている。

【0034】第11の発明は、第10の発明において、 $q$ セットの光受信セットの内、少なくとも一部のセットにおいて、 $n > m$ の条件が成立することを特徴とする。

【0035】上記のように、第11の発明では、少なくとも一部の光受信セットにおいて、 $n > m$ の条件が成立する。すなわち、当該一部の光受信セットでは、受信能力不足等の理由により、全ての階層のデジタル情報を復調できないので、重要度の高い階層のデジタル情報を復調することにより、できるだけ品質の高い再生データを得るようにしている。

【0036】第12の発明は、第9の発明において、光電気変換部からの出力信号を $t$ ( $t$ は、2以上の自然数)個に分岐する電気分配部をさらに備え、伝送路と、分岐部と、 $p$ 組の復調部と、 $p$ 組の階層合成部とで構成される光受信セットが、光分岐部によって分岐された $t$ 個の電気信号に対応して、 $t$ セット設けられていることを特徴とする。

【0037】上記のように、第12の発明では、光電気変換部からの出力信号を $t$ 個の電気信号に分岐することにより、複数の受信器に同時に分配することを可能にしている。

【0038】第13の発明は、第12の発明において、 $t$ セットの光受信セットの内、少なくとも一部のセットにおいて、 $n > m$ の条件が成立することを特徴とする。

【0039】上記のように、第13の発明では、少なくとも一部の光受信セットにおいて、 $n > m$ の条件が成立する。すなわち、当該一部の光受信セットでは、受信能力不足等の理由により、全ての階層のデジタル情報を復調できないので、重要度の高い階層のデジタル情報を復調することにより、できるだけ品質の高い再生データを得るようにしている。

【0040】第14の発明は、第9～13のいずれかの発明において、光伝送路の全伝送帯域を低域から高域にかけて第1～第 $n$ の情報伝送帯域に分割し、各帯域内には、互いに異なる周波数の $p$ 個の搬送波を設定し、 $p$ チャンネルのデジタル信号のそれぞれに対して割り当てられる第1～第 $n$ の搬送波は、第1～第 $n$ の情報伝送帯域から1つずつピックアップされることを特徴とする。



【0041】上記のように、第14の発明では、 $p$ チャンネルのデジタル信号を同時に光伝送する場合、光伝送路の全伝送帯域を低域から高域にかけて第1～第 $n$ の情報伝送帯域に分割し、各帯域内には、互いに異なる周波数の $p$ 個の搬送波を設定する。そして、 $p$ チャンネルのデジタル信号のそれぞれに対して割り当てられる第1～第 $n$ の搬送波を、第1～第 $n$ の情報伝送帯域から1つずつピックアップするようにしている。

【0042】第15の発明は、第1～14のいずれかの発明において、アナログ信号をデジタル信号に変換して階層変換部に入力するアナログ／デジタル変換部と、階層合成部から出力されたデジタル信号をアナログ信号に再変換するデジタル／アナログ変換部とをさらに備えている。

【0043】上記のように、第15の発明では、映像データや音声データ等のアナログ信号をデジタル信号に変換した後、光伝送するようにしている。

【0044】第16の発明は、周波数多重されたデジタル変調信号を光信号に変換して光伝送路上に送信する光送信装置であって、与えられたデジタル信号を、所定の階層化方式に従い、元のデータを構成する上での重要度に応じて、 $n$  ( $n$ は、2以上の自然数)個の階層に分割し、重要度の高いものから順番に並べられた第1～第 $n$ のデジタル情報として出力する階層分離部と、第1～第 $n$ のデジタル情報に個別的に割り当てられた互いに周波数の異なる第1～第 $n$ の搬送波を、当該デジタル情報でデジタル変調して、第1～第 $n$ のデジタル変調信号を出力する変調部と、変調部から出力された第1～第 $n$ のデジタル変調信号を周波数多重する多重部と、多重部から出力された電気信号を光信号に変換して光伝送路上に送出する電気光変換部とを備えている。

【0045】上記のように、第16の発明では、伝送すべきデジタル信号を、デジタル信号に変換後、元のデータを構成する上での重要度に応じて、複数階層のデジタル情報に分割し、各階層毎に割り当てられた互いに異なる周波数の搬送波を、当該デジタル情報でデジタル変調し、全てのデジタル変調信号を周波数多重して一括光伝送するようにしている。

【0046】従って、第16の発明によれば、伝送信号を構成する上での重要度に応じて、伝送情報に対して種々の操作ないし伝送制御が可能となる。その結果、高品質、低コストで、かつ発展性に優れた光伝送システムを実現することができる。

#### 【0047】

##### 【発明の実施の形態】

##### (1) 第1の実施例

図1は、本発明の第1の実施例に係る光伝送システムの構成を示す図である。図1において、本実施例の光伝送システムは、アナログ／デジタル変換部101と、階層合成部102と、変調部103と、多重部104と、

電気光変換部105と、光伝送路106と、光電気変換部107と、伝送路108と、分岐部109と、復調部110と、階層合成部112と、デジタル／アナログ変換部113とを備えている。また、変調部103は、第1～第4のデジタル変調回路1031～1034を含み、復調部110は、第1～第4のフィルタ1101～1104と、第1～第4のデジタル復調回路1111～1114を含む。

【0048】次に、第1の実施例の光伝送システムの動作について説明する。アナログ／デジタル変換部101は、例えば映像信号のようなアナログ信号をサンプリングおよび量子化して、デジタル信号に変換する。階層分離部102は、このデジタル信号を、所定の階層化方式に従って、元のアナログ信号を構成する上での重要度に応じて、複数(図1では4つ)のグループのデジタル情報 $D_1 \sim D_4$ に分割する。変調部103内において、第1～第4のデジタル変調回路1031～1034は、これら第1～第4グループのデジタル情報 $D_1 \sim D_4$ に各々対応して設けられ、互いに異なる4つの周波数 $f_1, f_2, f_3, f_4$ の搬送波を用いて、当該グループのデジタル情報をデジタル変調信号に変換し、出力する。例えば、第1のデジタル変調回路1031は、周波数 $f_1$ の搬送波を用いて、第1グループのデジタル情報 $D_1$ をデジタル変調信号に変換する。なお、第1～第4の搬送波の周波数配置の例を、図2に示す。すなわち、本実施例では、最重要な第1グループのデジタル情報 $D_1$ の伝送に使用する搬送波周波数 $f_1$ を、最も低周波に配置し、重要度の最も低い第4のデジタル情報 $D_4$ の伝送に使用する搬送波周波数 $f_4$ を、最も高周波に配置する。

【0049】多重部104は、第1～第4のデジタル変調回路1031～1033から出力された全てのデジタル変調信号を周波数多重する。この周波数多重されたデジタル変調信号は、電気光変換部105で光信号に変換された後、光伝送路106を介して伝送される。光電気変換部107は、伝送されてきた光信号を電気信号に再変換する。この再変換によって得られた電気信号は、伝送路108を介して伝送され、分岐部109で4分岐された後、復調部110内の第1～第4のフィルタ1101～1104に入力される。第1～第4のフィルタ1101～1104、および第1～第4のデジタル復調回路1111～1114は、上記第1～第4グループのデジタル情報 $D_1 \sim D_4$ に対応して設けられ、当該デジタル変調信号のみを透過し、当該グループのデジタル情報を出力する。例えば、第1のデジタル復調回路1111は、第1グループのデジタル情報 $D_1$ を復調し、出力する。階層合成部112は、上記所定の階層化方式の逆の過程に従って、第1～第4グループのデジタル情報 $D_1 \sim D_4$ を、1つのデジタル信号に合成する。デジタル／アナログ変換部113は、階層



合成部112の出力をデジタル／アナログ変換することにより、アナログ信号を再生する。

【0050】上記所定の階層化方式としては、以下のような方式がある。例えば、このデジタル信号の量子化ビット数が“8”であり、下位より、 $b_1$  (LSB: Least Significant Bit),  $b_2$ ,  $b_3$ ,  $b_4$ ,  $b_5$ ,  $b_6$ ,  $b_7$ ,  $b_8$  (MSB: Most Significant Bit)とした場合、最も重要なMSB近傍の2ビット $b_8$ ,  $b_7$ を第1のデジタル情報グループとし、 $b_6$ ,  $b_5$ を第2のデジタル情報グループとし、 $b_4$ ,  $b_3$ を第3のデジタル情報グループとし、最も重要度の低いLSB近傍の2ビット $b_2$ ,  $b_1$ を第4のデジタル情報グループとし、2ビットずつ分割する方法である。また、デジタル信号に、所定の時間／周波数変換を施して得られた各周波数成分情報について、これを4分割し、直流成分近傍の情報を第1グループのデジタル情報とし、最も高周波を表わす情報を第4グループのデジタル情報とする方法がある。なお、上記所定の時間／周波数変換としては、フーリエ変換や、離散コサイン変換(DCT)などがある。

#### 【0051】(2) 第2の実施例

図3は、本発明の第2の実施例に係る光伝送システムの構成を示す図である。図3において、本実施例の光伝送システムは、アナログ／デジタル変換部101と、階層分離部102と、変調部103と、多重部104と、電気光変換部105と、光伝送路106と、光電気変換部107と、伝送路108と、分岐部109と、復調部110と、階層合成部112と、デジタル／アナログ変換部113とを備えている。また、変調部103は、第1～第3のデジタル変調回路1031～1033を含む。また、復調部110は、第1～第3のフィルタ1101～1103と、第1～第3のデジタル復調回路1111～1113を含む。

【0052】次に、上記第2の実施例の光伝送システムの動作について説明する。各構成要素の詳しい動作は、前述の第1の実施例と同様であるため、ここでは特徴的な動作についてのみ説明を行う。本実施例は、受信者が、品質の高い信号を受信する必要のない場合、あるいは品質の高い信号を受信できない場合の構成を示している。すなわち、分岐部109は、伝送路108から出力される信号を3分岐し、復調部110内の第1～第3のフィルタ1101～1103に各々入力する。第1～第3のフィルタ1101～1103、および第1～第3のデジタル復調回路1111～1113は、上記第1～第3グループのデジタル情報 $D_1 \sim D_3$ に対応して設けられ、これらを復調して出力する。従って、受信側において、第4グループのデジタル情報 $D_4$ は復調されない。階層合成部112は、この第4グループのデジタル情報 $D_4$ を用いずに、第1～第3グループのデジ

タル情報 $D_1 \sim D_3$ のみを用いてデジタル信号を合成し、出力する。なお、受信者が、品質の高い信号を受信できないケースとしては、例えば伝送路108の伝送可能帯域が狭く、第4のデジタル情報 $D_4$ の伝送を司るデジタル変調信号を送送できない場合などがある。

#### 【0053】(3) 第3の実施例

図4は、本発明の第3の実施例に係る光伝送システムの構成を示す図である。図4において、本実施例の光伝送システムは、第1～第3のアナログ／デジタル変換部4011～4013と、第1～第3の階層合成部4021～4023と、第1～第3の変調部4031～4033と、チャンネル多重部404と、電気光変換部405と、光伝送路406と、光電気変換部407と、伝送路408と、チャンネル分岐部409と、第1～第3の復調部4101～4103と、第1～第3の階層合成部4121～4123と、第1～第3のデジタル／アナログ変換部4131～4133とを備えている。なお、第1および第2の実施例と同様に、各変調部は4つのデジタル変調回路を備え、各復調部は4組のフィルタおよびデジタル復調回路を備えている。

【0054】次に、第3の実施例の光伝送システムの動作について説明する。本実施例は、前述した第1の実施例を、多チャンネル(図4では3チャンネル:  $C_1$ ,  $C_2$ ,  $C_3$ )伝送に拡張した場合の構成を示している。例えば、第1チャンネルの信号 $C_1$ は、第1のアナログ／デジタル変換部4011によってデジタル信号に変換された後、第1の階層分離部4021によって、重要度の異なる4グループのデジタル情報 $D_{11} \sim D_{14}$ に分割され、第1の変調部4031において、互いに異なる周波数 $f_{11} \sim f_{14}$ の4つの搬送波を用いて、各々デジタル変調信号に変換される。

【0055】図5は、第1～第3チャンネルの信号に各々割り当てられる4つの搬送波の周波数配置の一例を示している。図5に示すように、各チャンネルの信号に対する第1～第4の搬送波は、第1の実施例でも説明したごとく、重要なデジタル情報の伝送を司る搬送波を低周波側に、重要度の低いデジタル情報の伝送を司る搬送波を高周波側に配置するものとする。また、全伝送帯域を低周波数域から高周波数域にかけて第1～第4の情報伝送帯域に分割し、全チャンネルの信号に対する全ての第1の搬送波を第1の情報伝送帯域に、全ての第2の搬送波を第2の情報伝送帯域に、全ての第3の搬送波を第3の情報伝送帯域に、全ての第4の搬送波を第4の情報伝送帯域に配置する。なお、本実施例では、全伝送帯域を4つの情報伝送帯域に分割し、各情報伝送帯域内に、全てのチャンネルのいずれかの階層の信号が含まれるようにしているが、このような情報伝送帯域を設けることなく、全チャンネルの全階層情報の重要度を1元的に順位付けし、この順位に従って各搬送波を周波数軸上で配置するようにしてもよい。

【0056】チャンネル多重部404は、全変調部4031~4033から出力される全てのデジタル変調信号を周波数多重する。この周波数多重信号は、電気光変換部405~伝送路408を介して伝送された後、チャンネル分岐部409において3分岐され、各チャンネル信号に対応して設けられた第1~第3の復調部4101~4103に各々入力される。例えば、第1の復調部4101では、第1チャンネルの信号 $C_1$ に対応する周波数 $f_{11}$ ,  $f_{12}$ ,  $f_{13}$ ,  $f_{14}$ の4つのデジタル変調信号のみが透過、復調され、4グループのデジタル情報 $D_{11}$ ,  $D_{12}$ ,  $D_{13}$ ,  $D_{14}$ として出力される。そして、第1の階層合成部4121によって1つのデジタル信号に合成され、第1のデジタル/アナログ変換部4131によってアナログ信号に再変換されて出力される。

#### 【0057】(4) 第4の実施例

図6は、本発明の第4の実施例に係る光伝送システムの構成を示す図である。図6において、本実施例の光伝送システムは、第1~第3のアナログ/デジタル変換部4011~4013と、第1~第3の階層合成部4021~4023と、第1~第3の変調部4031~4033と、チャンネル多重部404と、電気光変換部405と、光伝送路406と、光分配部600と、第1および第2の光電気変換部6071および6072と、第1および第2の伝送路6081および6082と、第1および第2のチャンネル分岐部6091および6092と、第1~第6の復調部6101~6106と、第1~第6の階層合成部6121~6126と、第1~第6のデジタル/アナログ変換部6131~6136とを備えている。なお、前述した第1~第3の実施例と同様、各変調部は4つのデジタル変調回路を備え、各復調部は4組のフィルタおよびデジタル復調回路を備えている。

【0058】次に、第4の実施例の光伝送システムの動作について説明する。本実施例は、第3の実施例を、受信者（または光電気変換部）が複数（図6では2つ）の場合に適用した構成を示している。第1~第3チャンネル信号 $C_1 \sim C_3$ は、各々4つの階層のデジタル情報グループに分離後、各々デジタル変調信号に変換され、周波数多重され、光信号に変換され光伝送路406を伝送される。この光信号は、光分配部600によって2分岐された後、2つの光電気変換部、すなわち第1および第2の光電気変換部6071および6072に入力される。例えば、第1の光電気変換部6071は、受信した光信号を電気信号に再変換し、この再変換によって得られた電気信号は、第1の伝送路6081を介して伝送された後、第1のチャンネル分岐部6091で3分岐され、第1の受信者が有する3つの復調部、すなわち第1~第3の復調部6101~6103に各々入力される。例えば、第1の復調部6101において復調された第1チャンネルの信号 $C_1$ に対応する4つのグループのデジタル情報 $D_{11}$ ,  $D_{12}$ ,  $D_{13}$ ,  $D_{14}$ は、第1の階層

合成部6121によって1つのデジタル信号に合成され、第1のデジタル/アナログ変換部6131によってアナログ信号に再変換される。

【0059】なお、第2の受信者が有する各復調部、各階層合成部、各デジタル/アナログ変換部は、第2の実施例と同様、第2の受信者が要求する信号品質に応じて、あるいは伝送路の伝送可能帯域等に応じて、復調、合成およびデジタル/アナログ変換を行う。例えば、図7に示すように、第2の伝送路6082の伝送可能帯域が狭い場合、受信側では、各チャンネル信号の第1~第3グループのデジタル情報（第1~第3の情報伝送帯域に配置される第1~第3の搬送波が伝送する情報）のみを復調し、各アナログ信号を再生する。

#### 【0060】(5) 第5の実施例

図8は、本発明の第5の実施例に係る光伝送システムの構成を示す図である。図8において、本実施例の光伝送システムは、第1~第3のアナログ/デジタル変換部4011~4013と、第1~第3の階層合成部4021~4023と、第1~第3の変調部4031~4033と、チャンネル多重部404と、電気光変換部405と、光伝送路406と、光電気変換部407と、電気分配部800と、第1および第2の伝送路6081および6082と、第1および第2のチャンネル分岐部6091および6092と、第1~第6の復調部6101~6106と、第1~第6の階層合成部6121~6126と、第1~第6のデジタル/アナログ変換部6131~6136とを備えている。なお、前述した第1~第4の実施例同様、各変調部は4つのデジタル変調回路を備え、各復調部は4組のフィルタおよびデジタル復調回路を備えている。

【0061】次に、上記第5の実施例の光伝送システムの動作について説明する。本実施例は、上述の第4の実施例と同様に、第3の実施例を、受信者が2の場合に適用した場合の構成であるが、信号の2分岐を光信号レベルで行なう第4の実施例と異なり、電気信号レベルで2分岐を行なうものである。すなわち、第1~第3チャンネル信号 $C_1 \sim C_3$ は、各々4つの階層のデジタル情報グループに分離後、各々デジタル変調信号に変換、周波数多重され、光信号に変換され、光伝送路を伝送された後、1つの光電気変換部407によって電気信号に再変換される。この電気信号は、電気分配部800によって2分岐され、第1および第2の受信者の有する各チャンネル分岐部、すなわち、第1および第2のチャンネル分岐部6091および6092に各々入力される。チャンネル分岐部、復調部、階層合成部、デジタル/アナログ変換部は、各々第4の実施例と同様に、3チャンネルのアナログ信号 $C_1$ ,  $C_2$ ,  $C_3$ を再生する。なお、本実施例の場合も、第2の伝送路6082の伝送可能帯域に制限されて、第2の受信者では、第1~第3の情報伝送帯域によって伝送される第1~第3のディジタ

ル情報のみから、各アナログ信号を再生する。

【0062】なお、以上説明した各実施例では、アナログ信号をデジタル信号に変換した後、階層分割および多重化して光伝送するようにしているが、デジタルデータを階層分割および多重化して光伝送する場合にも本発明を適用することができる。この場合、例えば第1の実施例で言えば、アナログ／デジタル変換部101およびデジタル／アナログ変換部113が不要となる。他の実施例においても同様である。

【0063】従来技術の欄で述べたように、一般的に光伝送システムにおいて、搬送波周波数の高いデジタル変調信号の波形劣化は大きくなる。そのため、以上説明した各実施例では、重要度の高いデジタル情報を伝送する帯域として低周波数域を用い、重要度の低いデジタル情報を伝送する帯域として高周波数域を用いるようにしている。しかしながら、多チャンネルの信号の伝送時において特定の次数の歪みについての波形劣化を問題とする場合は、伝送特性の良好でない帯域が高域に分布しているとは限らないので、重要度の低いデジタル情報を伝送するために、高域以外の他の帯域が用いられる場合もある。例えば、3次歪みは、全伝送帯域中の中間帯域で大きくなるので、3次歪みによる波形劣化を問題とする場合、重要度の低いデジタル情報は、中間帯域を用いて伝送される。また、2次歪みは、全伝送帯域中の高域および低域で大きくなるので、2次歪みによる波形劣化を問題とする場合、重要度の低いデジタル情報は、高域または低域を用いて伝送される。

#### 【図面の簡単な説明】

【図1】本発明の第1の実施例に係る光伝送システムの構成を示すブロック図である。

【図2】本発明の第1の実施例の光伝送システムにおけるデジタル変調用搬送波の周波数配置の一例を示す図である。

【図3】本発明の第2の実施例に係る光伝送システムの構成を示すブロック図である。

【図4】本発明の第3の実施例に係る光伝送システムの構成を示すブロック図である。

【図5】本発明の第3の実施例の光伝送システムにおけるデジタル変調用搬送波の周波数配置の一例を示す図である。

【図6】本発明の第4の実施例に係る光伝送システムの構成を示すブロック図である。

【図7】本発明の第4の実施例の光伝送システムにおける使用可能伝送帯域の一例を示す図である。

【図8】本発明の第5の実施例に係る光伝送システムの構成を示すブロック図である。

【図9】従来の光伝送システムの第1の例を示すブロッ

ク図である。

【図10】従来の光伝送システムの第2の例を示すブロック図である。

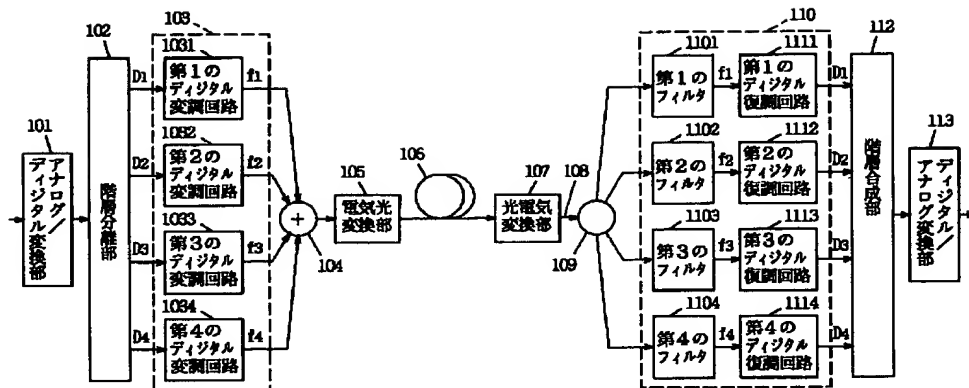
【図11】従来の光伝送システムの第3の例を示すブロック図である。

【図12】従来の光伝送システムの第3の例におけるデジタル変調用搬送波の周波数配置の一例を示す図である。

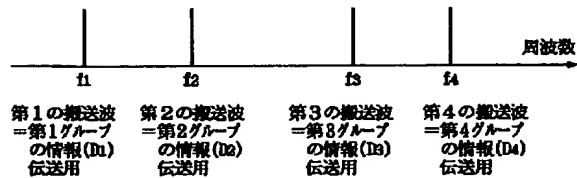
#### 【符号の説明】

101…アナログ／デジタル変換部  
102…階層分離部  
103…変調部  
1031～1034…第1～第4のデジタル変調回路  
104…多重部  
105…電気光変換部  
106…光伝送路  
107…光電気変換部  
108…伝送路  
109…分岐部  
110…復調部  
1101～1104…第1～第4のフィルタ  
1111～1114…第1～第4のデジタル復調回路  
112…階層合成部  
113…デジタル／アナログ変換部  
4011～4013…第1～第3のアナログ／デジタル変換部  
4021～4023…第1～第3の階層分離部  
4031～4033…第1～第3の変調部  
404…チャンネル多重部  
405…電気光変換部  
406…光伝送路  
407…光電気変換部  
408…伝送路  
409…チャンネル分岐部  
4101～4103…第1～第3の復調部  
4121～4123…第1～第3の階層合成部  
4131～4133…第1～第3のデジタル／アナログ変換部  
600…光分配部  
6071, 6072…第1, 第2の光電気変換部  
6081, 6082…第1, 第2の伝送路  
6091, 6092…第1, 第2のチャンネル分岐部  
6101～6106…第1～第6の復調部  
6121～6131…第1～第6の階層合成部  
6131～6136…第1～第6のデジタル／アナログ変換部  
800…電気分配部

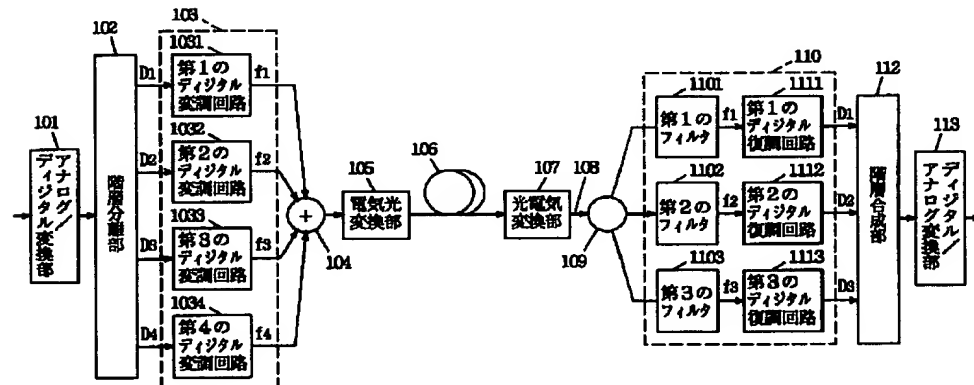
【図1】



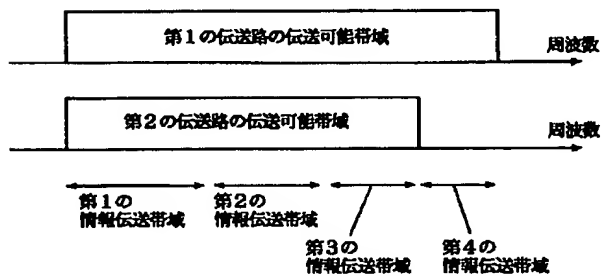
【図2】



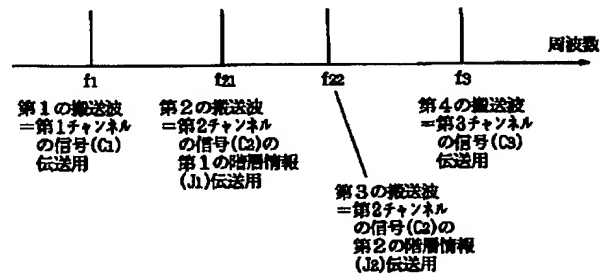
【図3】



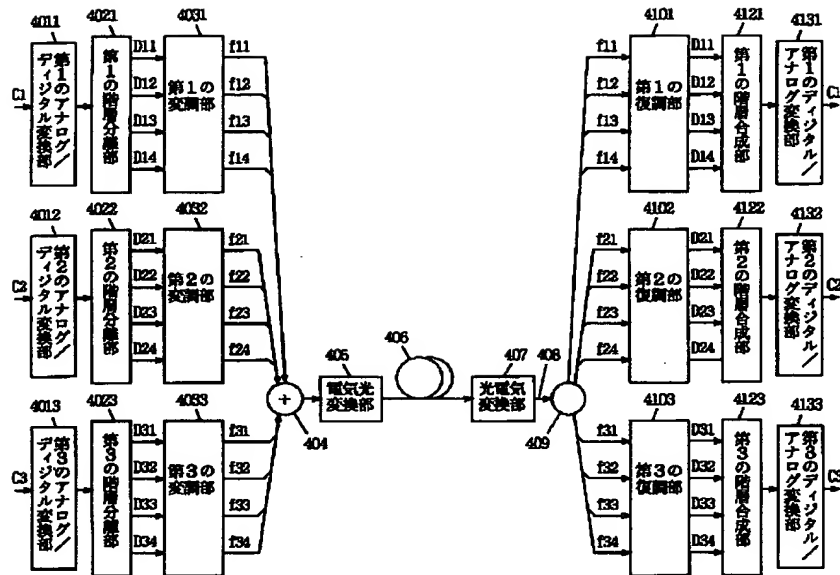
【図7】



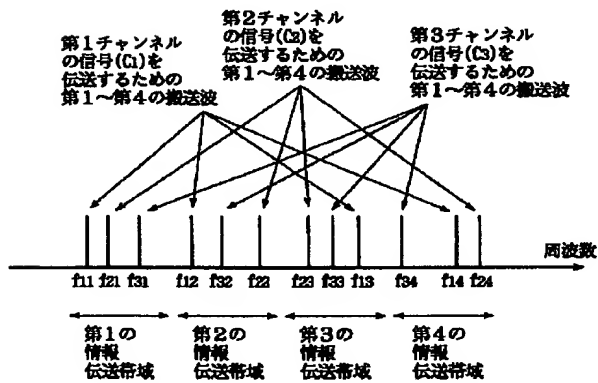
【図12】



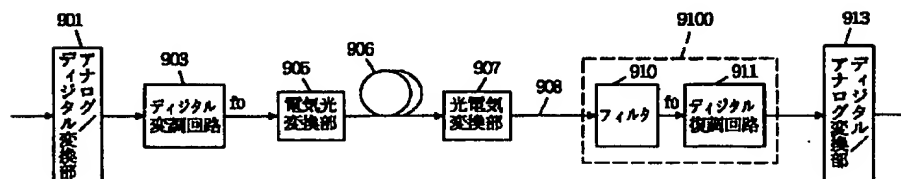
【図4】



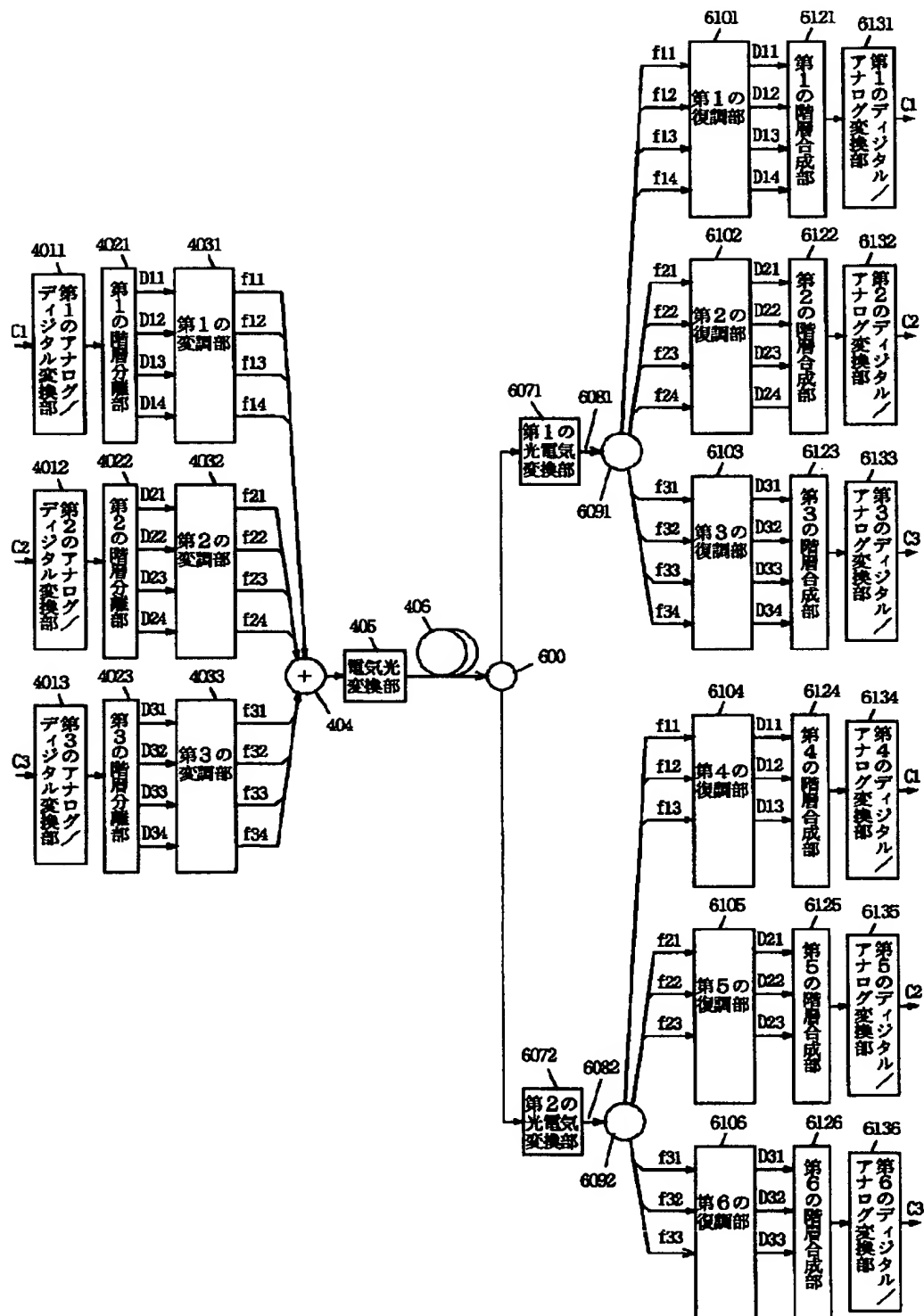
【図5】



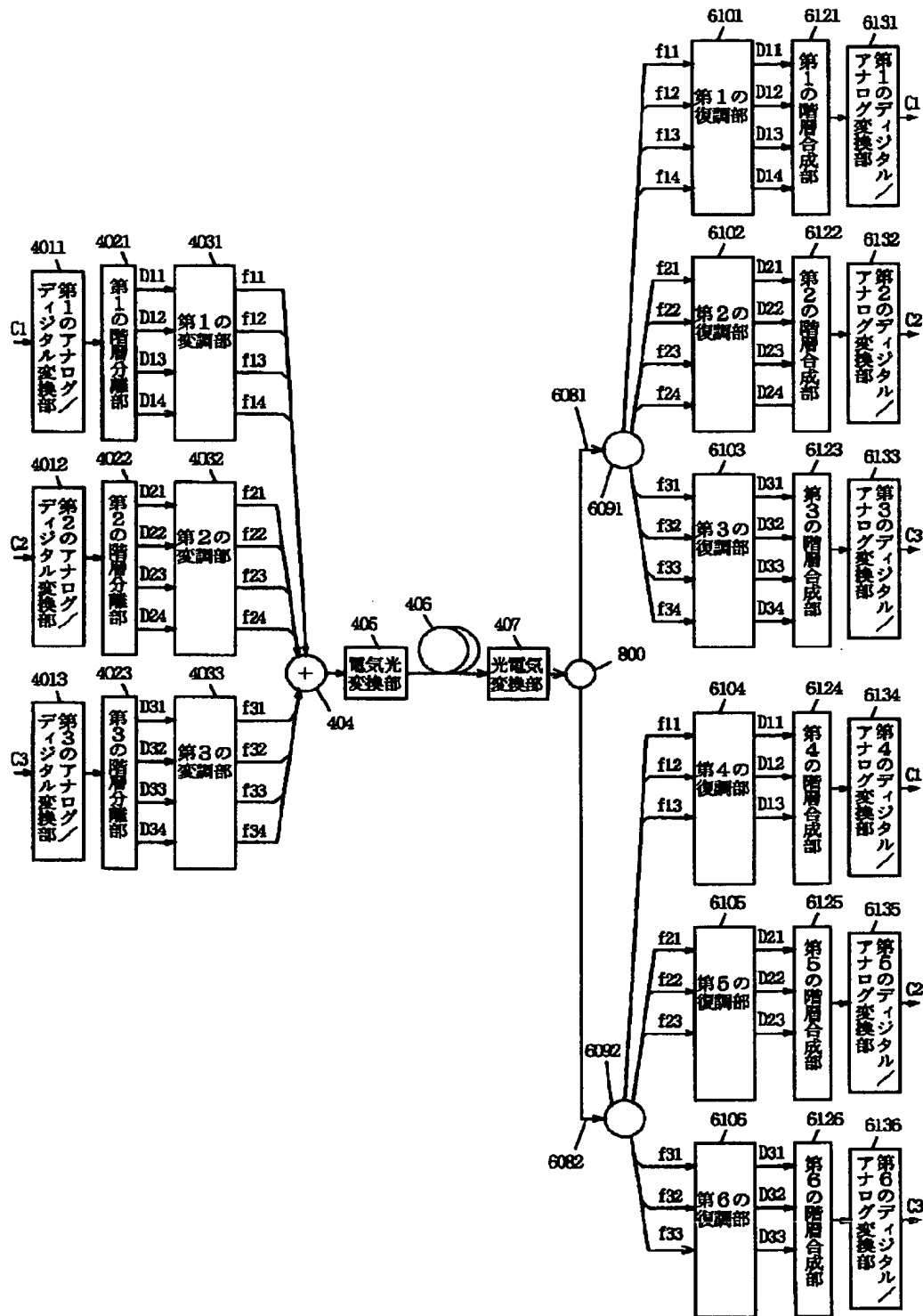
【図9】



【図6】

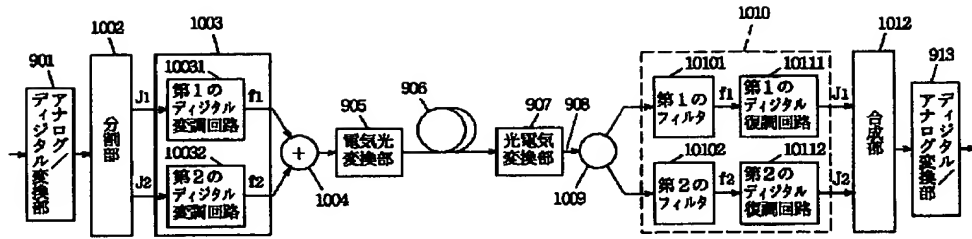


【図8】

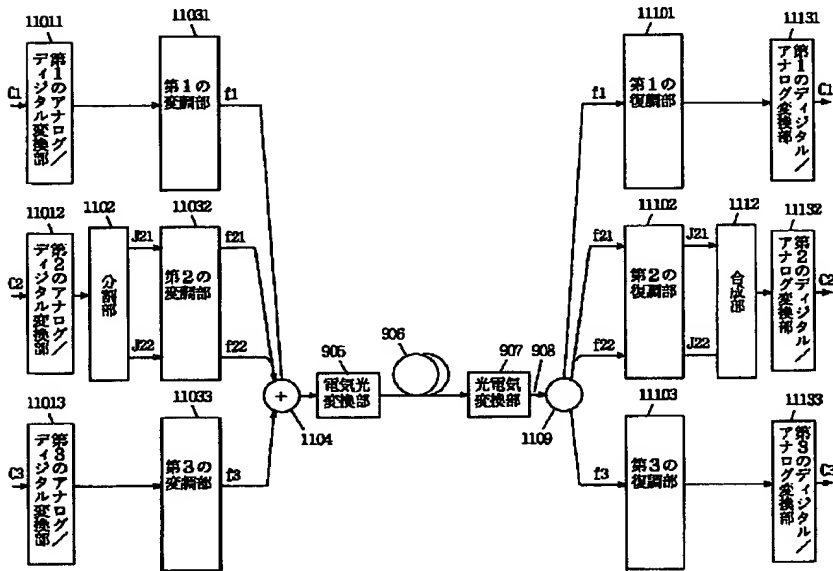




【図10】



【図11】







US006078412A

**United States Patent** [19]

Fuse et al.

[11] **Patent Number:** **6,078,412**[45] **Date of Patent:** **Jun. 20, 2000**[54] **OPTICAL TRANSMITTER AND OPTICAL TRANSMISSION SYSTEM USING THE SAME**[75] Inventors: **Masaru Fuse**, Toyonaka; **Kuniaki Utsumi**, Sanda, both of Japan[73] Assignee: **Matsushita Electric Industrial Co., Ltd.**, Osaka-fu, Japan[21] Appl. No.: **08/724,835**[22] Filed: **Oct. 3, 1996**[30] **Foreign Application Priority Data**

Mar. 10, 1995 [JP] Japan ..... 7-256146

[51] Int. Cl.<sup>7</sup> ..... **H04J 14/02**[52] U.S. Cl. .... **359/124; 359/181**

[58] Field of Search ..... 359/124-125, 359/133, 173, 181, 188; 370/480, 497

[56] **References Cited****U.S. PATENT DOCUMENTS**5,016,242 5/1991 Tang ..... 359/124  
5,351,148 9/1994 Maeda et al. .... 359/124*Primary Examiner*—Kinfe-Michael Negash*Attorney, Agent, or Firm*—Wenderoth, Lind & Ponack, L.L.P.[57] **ABSTRACT**

In a system for simultaneously optically transmitting a plurality of digital modulation signals using an analog SCM transmission technique, the degree of degradation of the waveform of a transmission signal or the magnitude of distortion thereof differs depending on bands, whereby there arises a difference in transmission quality among channels. Therefore, an analog signal to be transmitted is converted into a digital signal by an analog-to-digital converting portion, after which the digital signal is divided, by a hierarchy separating portion, into a plurality of groups of digital information depending on degrees of importance in constructing the original analog signal. A modulating portion digitally modulates carriers having different frequencies which are respectively assigned to the groups of digital information. A multiplexing portion frequency-multiplexes and simultaneously optically transmits all the digital modulation signals. In this case, the carrier corresponding to the digital information having a higher degree of importance is set on a lower frequency side, and the carrier corresponding to the digital information having a lower degree of importance is set on a higher frequency side. Consequently, it is possible to minimize the effect of the degradation and the distortion caused in the transmission on received and reproduced data, whereby high-quality transmission is possible.

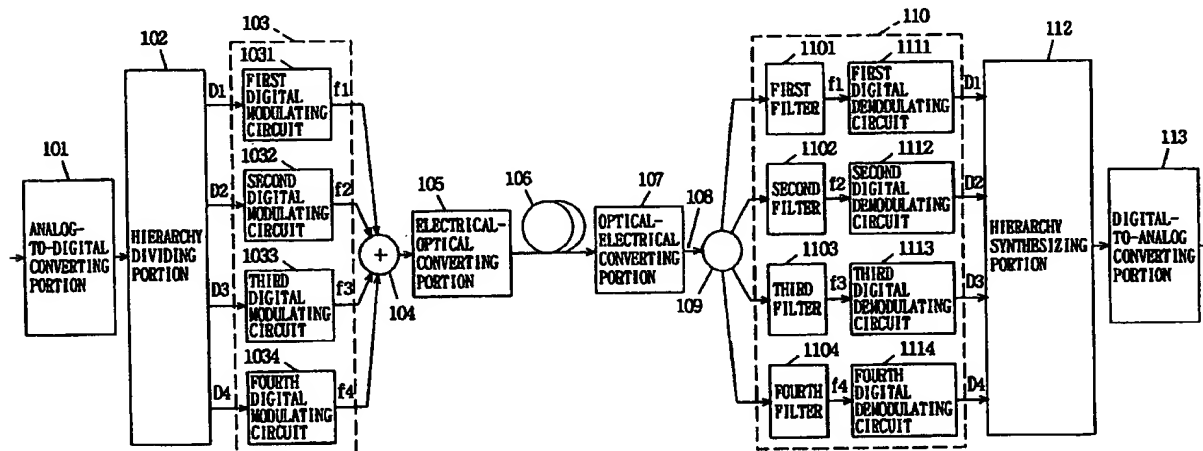
**19 Claims, 12 Drawing Sheets**

FIG. 1

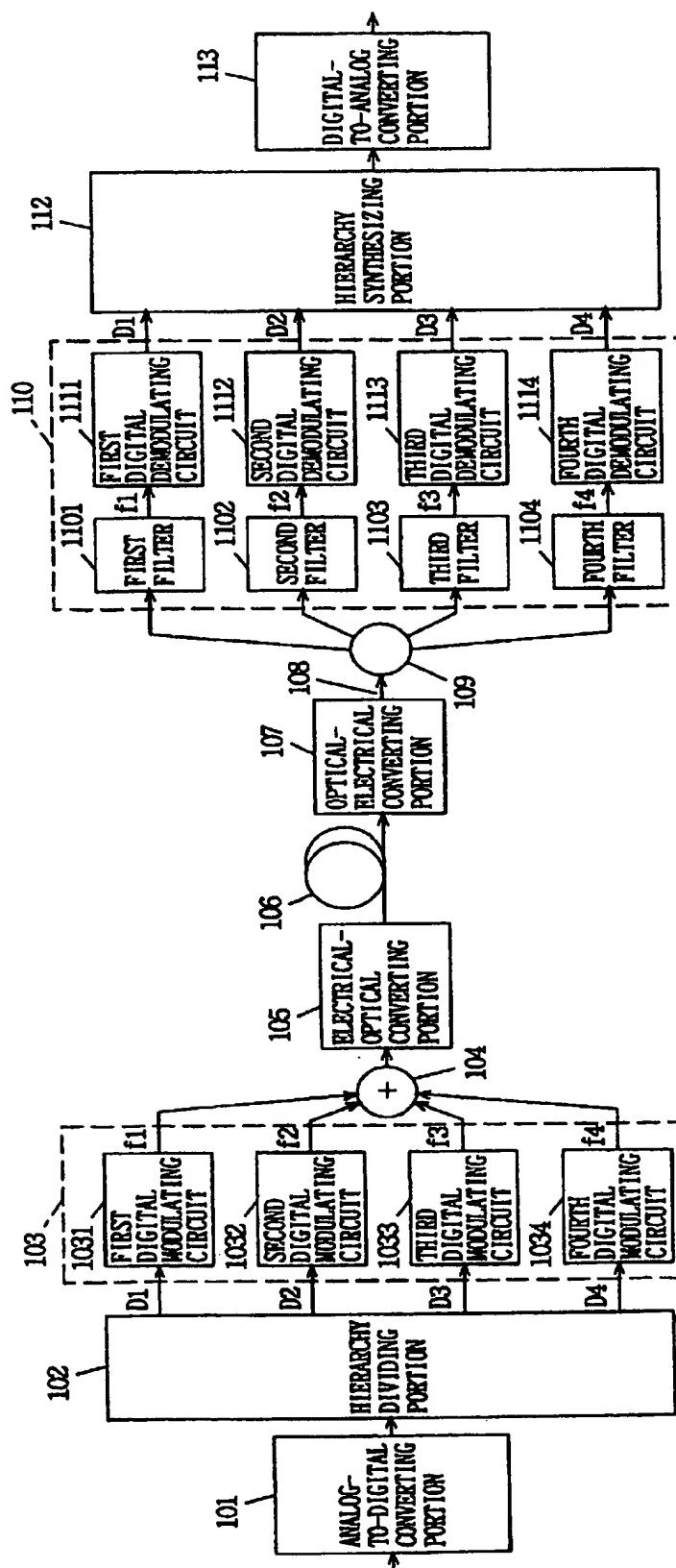


FIG. 2

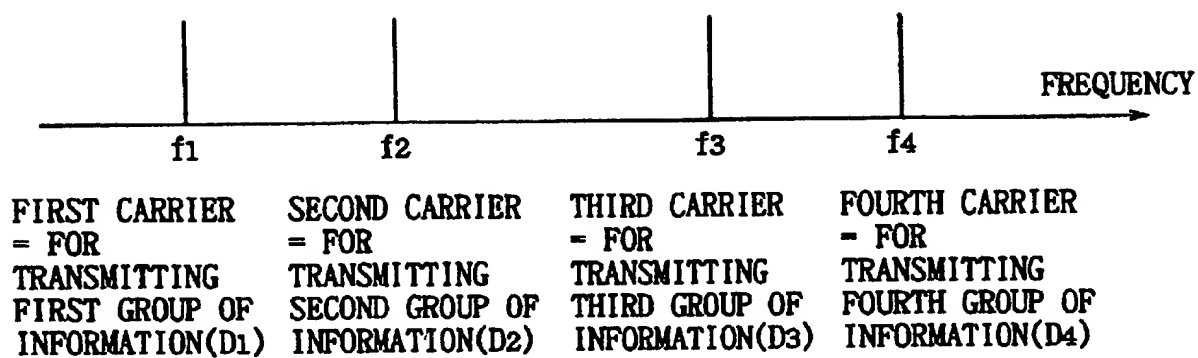


FIG. 3

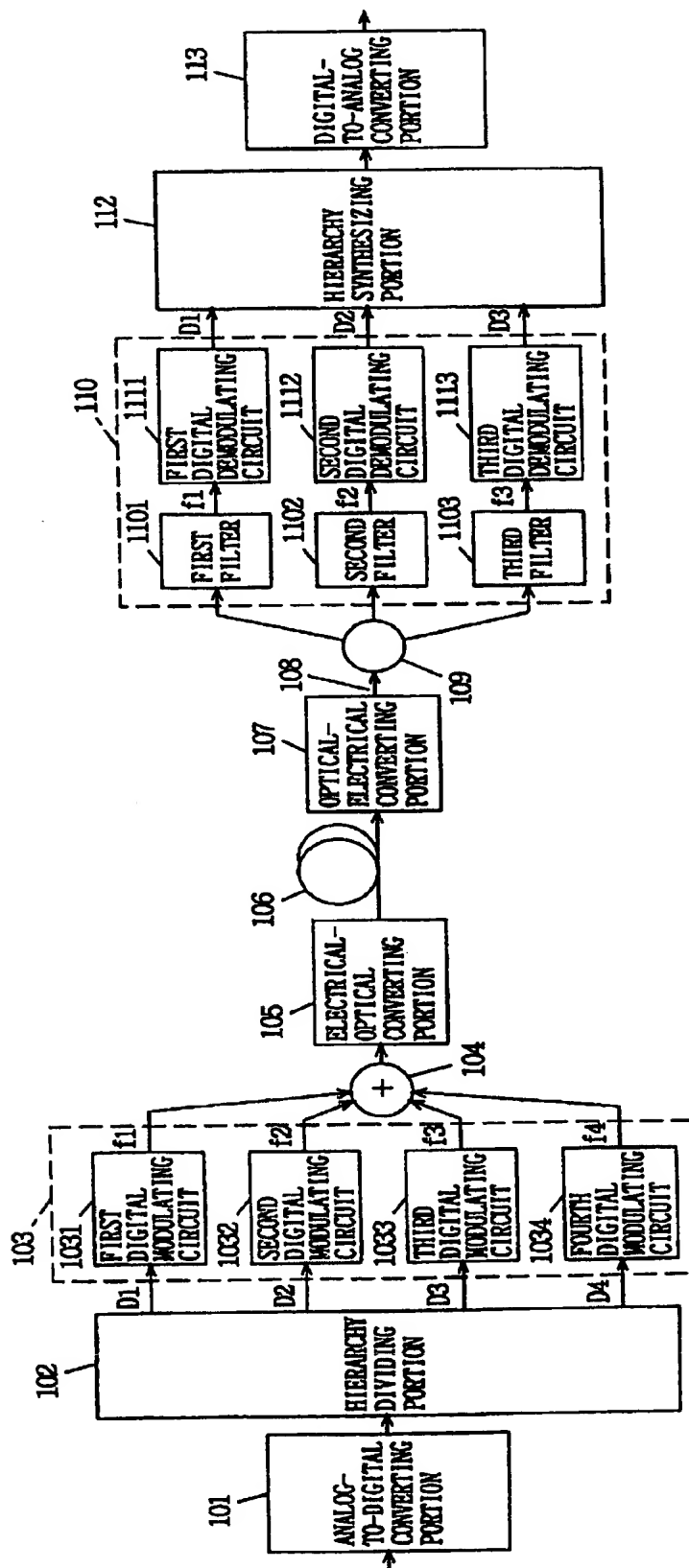


FIG. 4

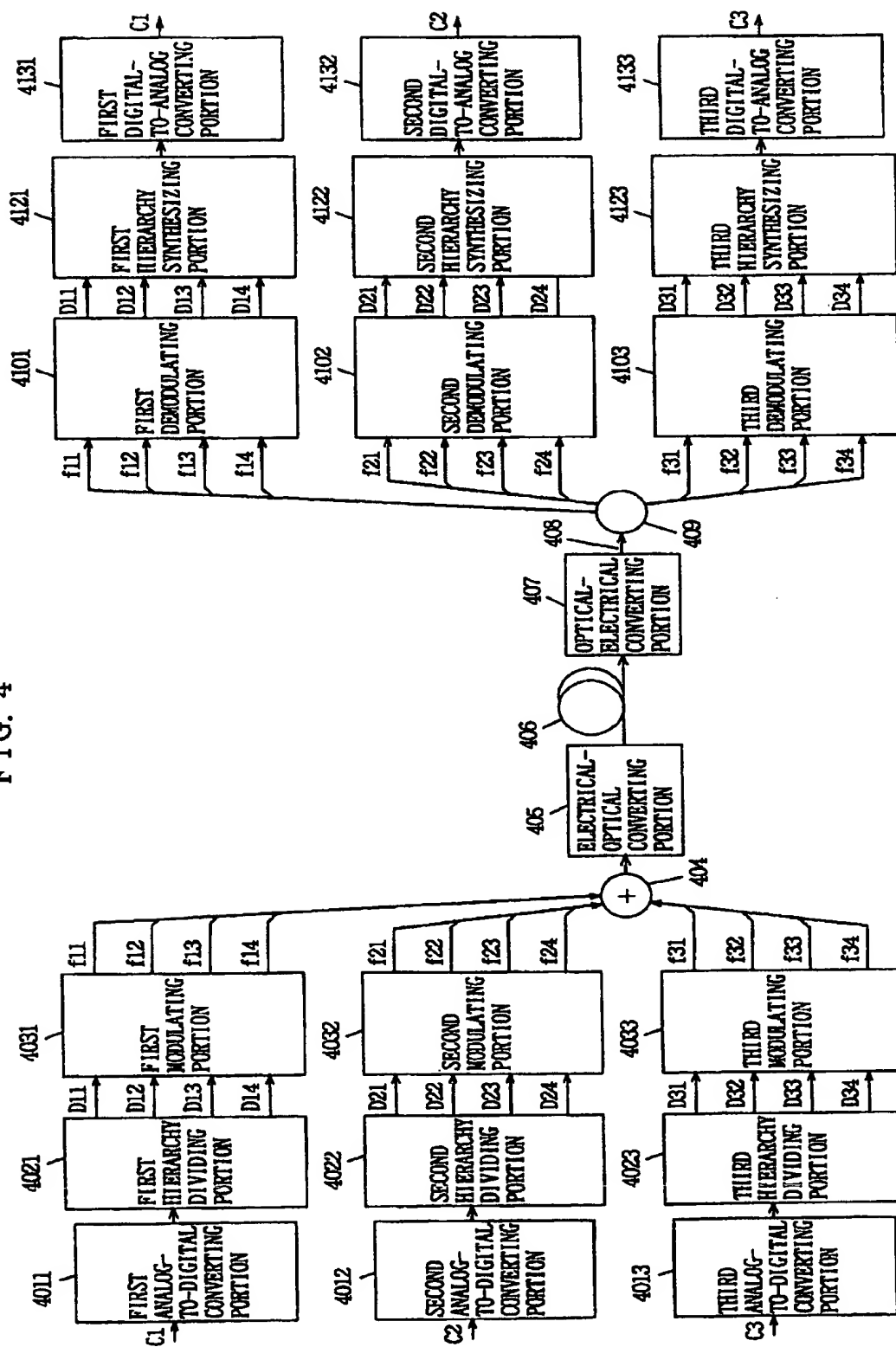




FIG. 5

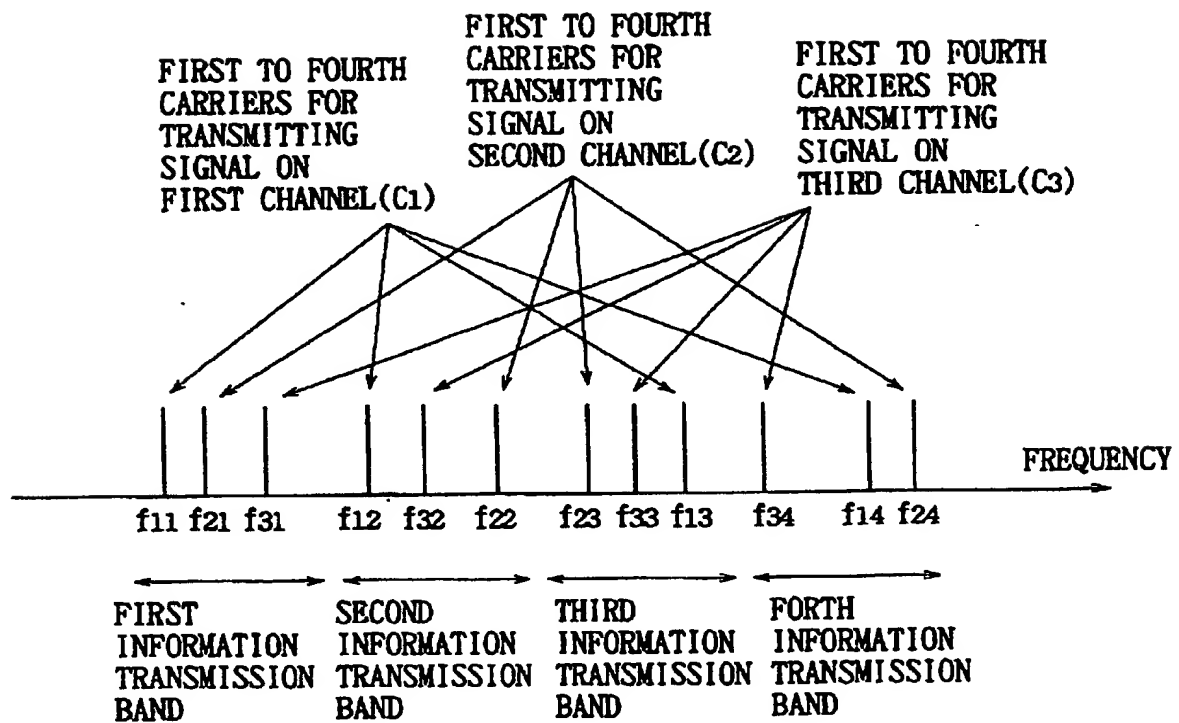


FIG. 6

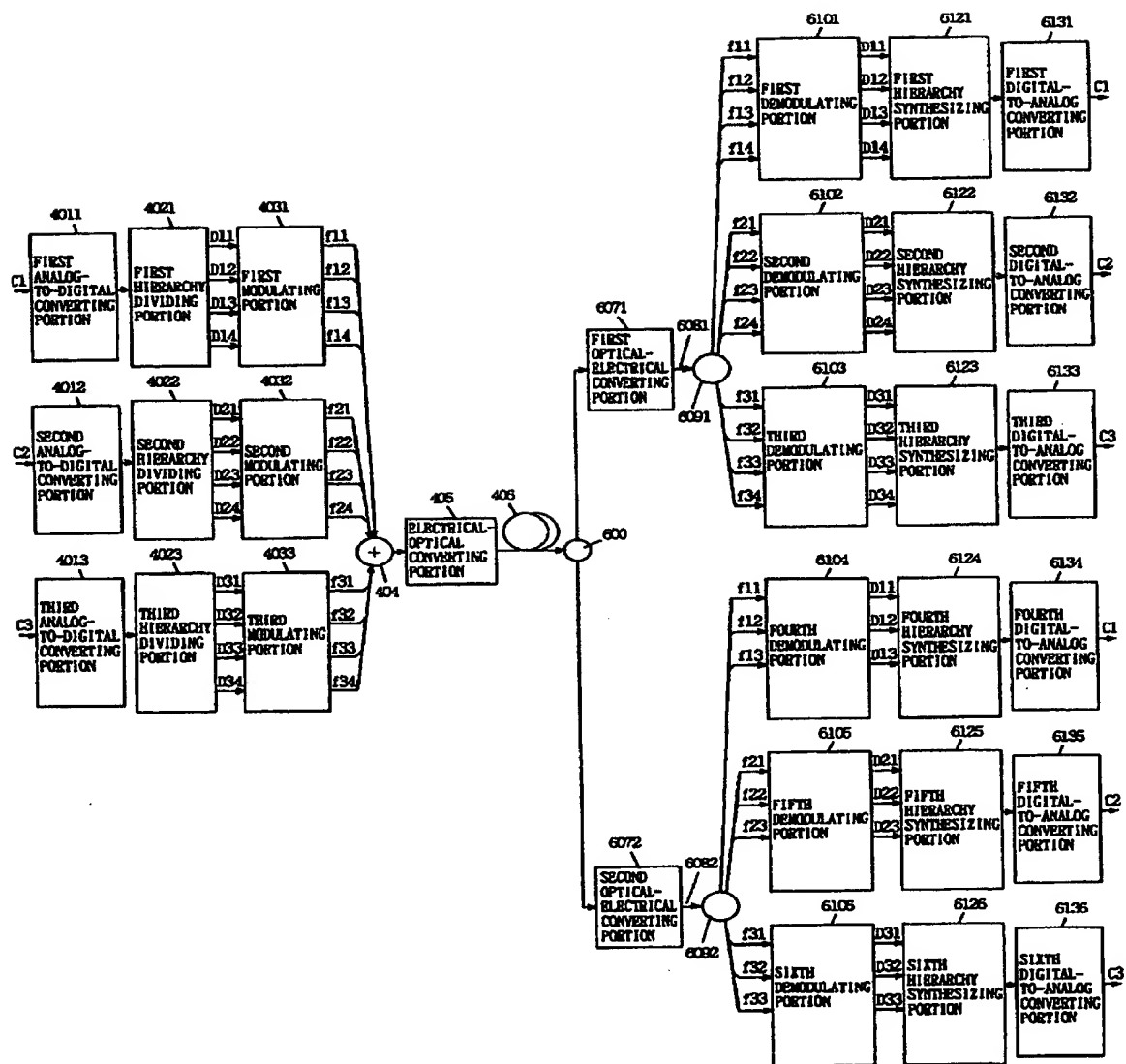


FIG. 7

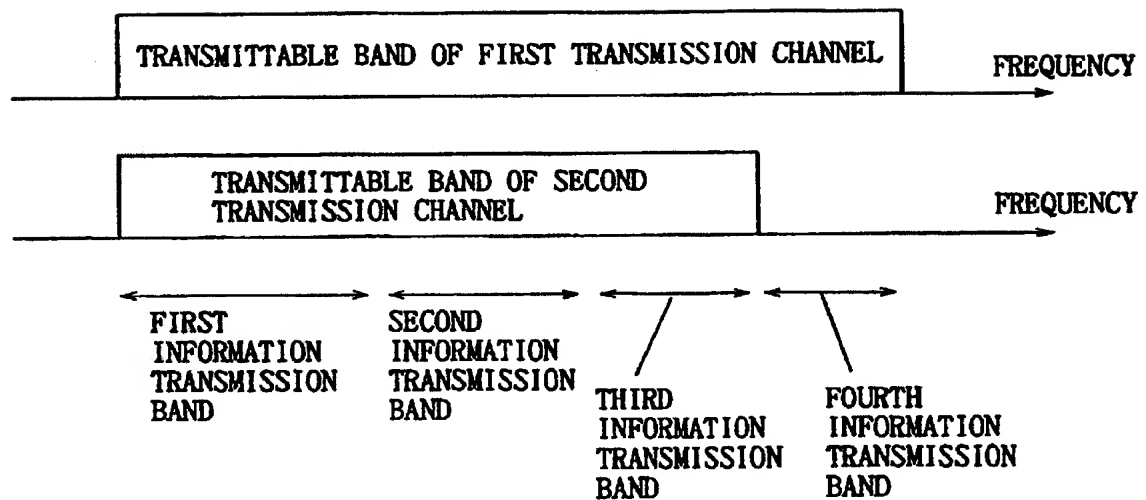


FIG. 8

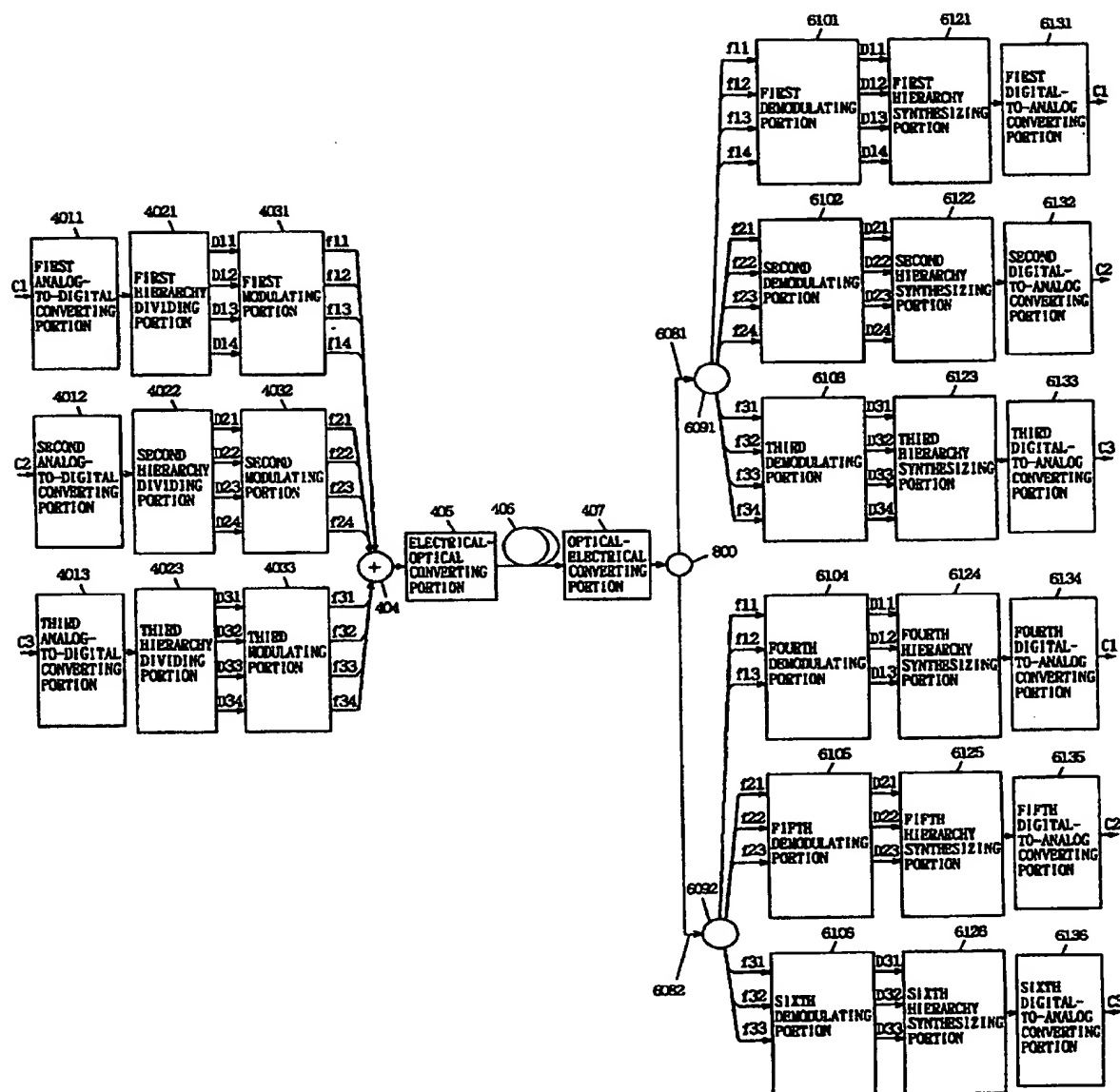


FIG. 9 PRIOR ART

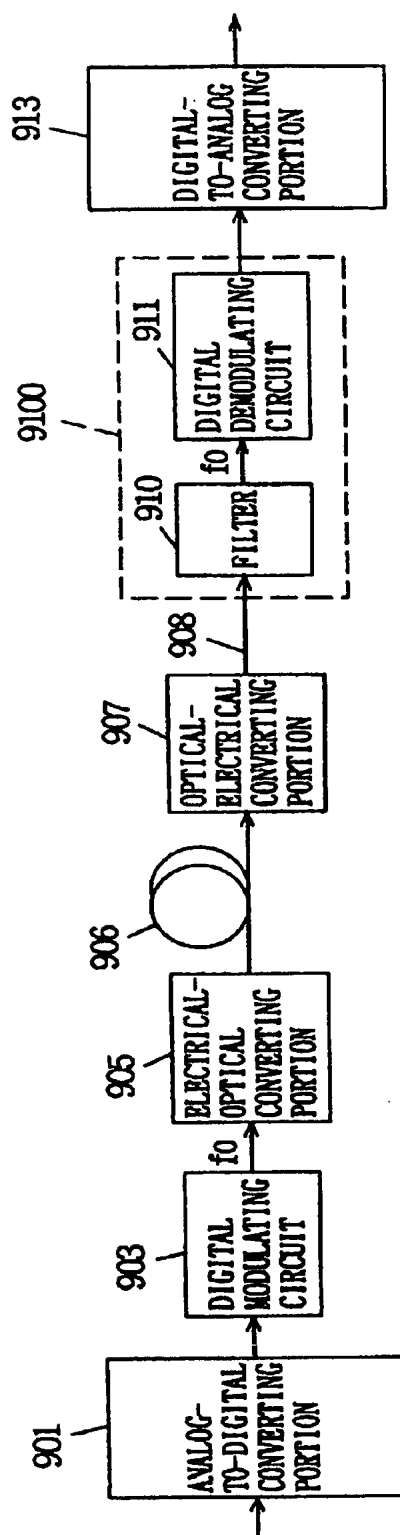


FIG. 10 PRIOR ART

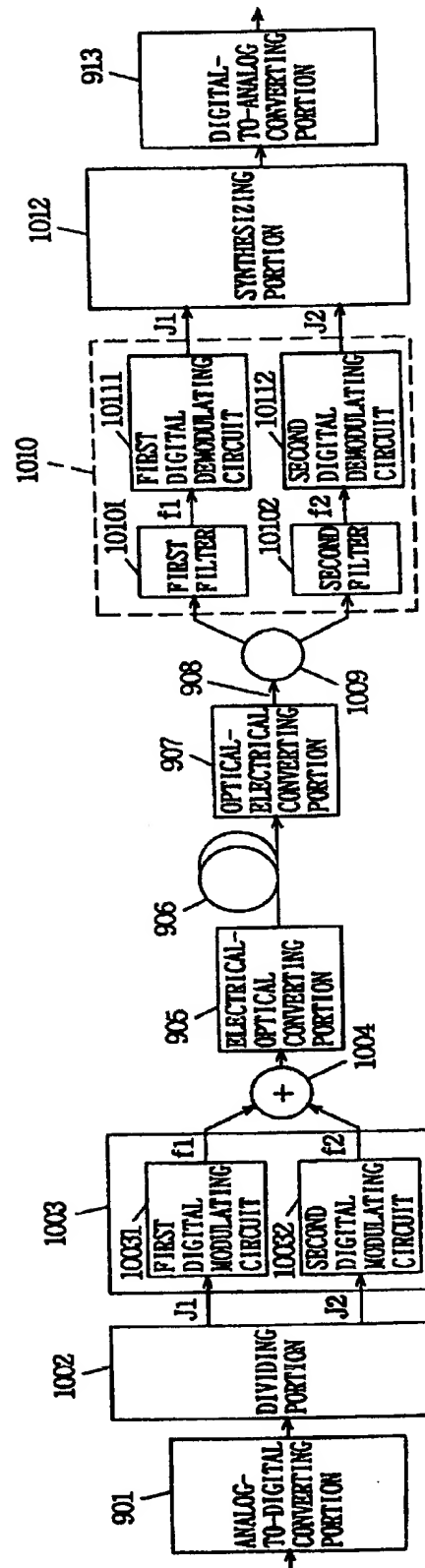


FIG. 11 PRIOR ART

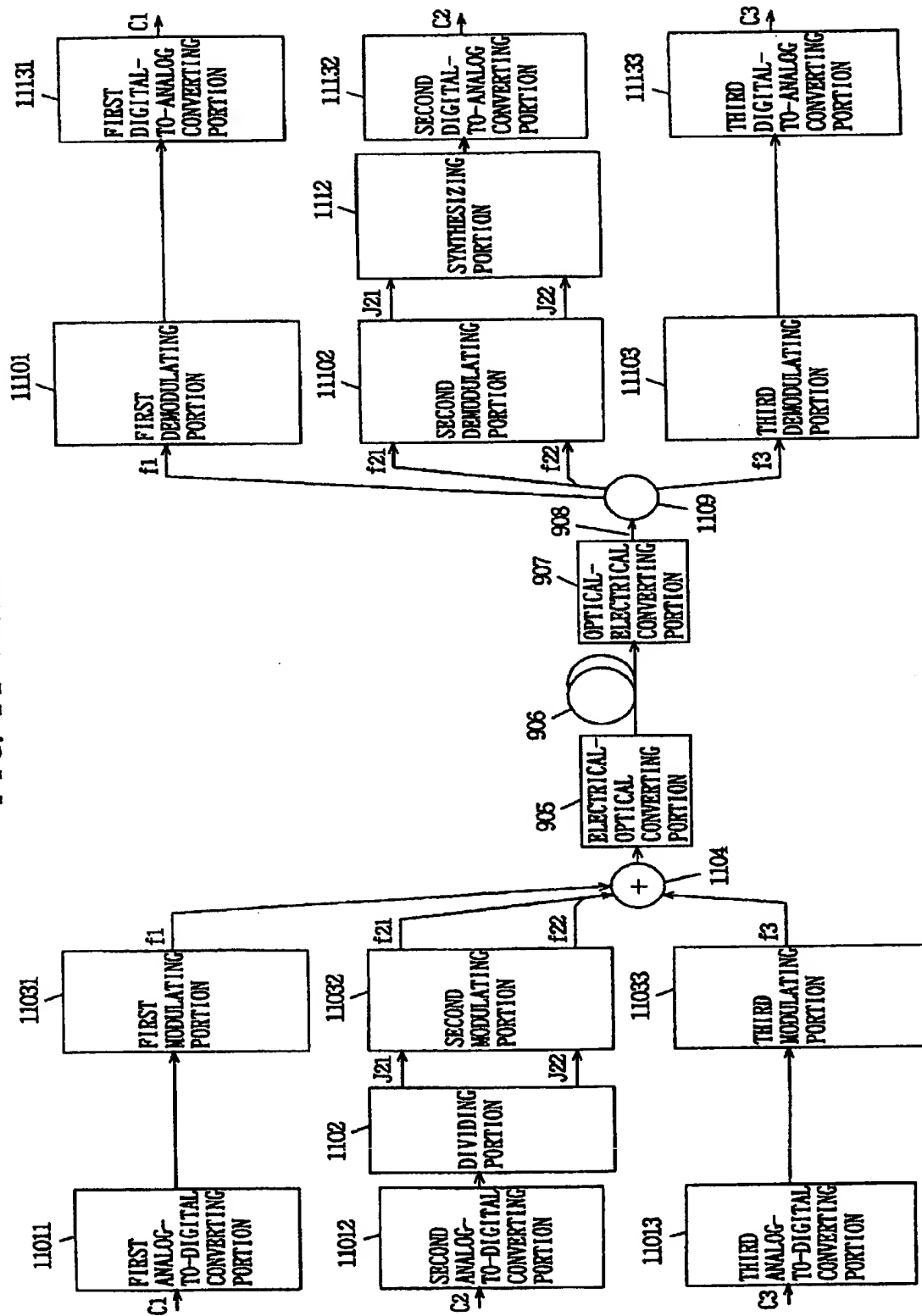
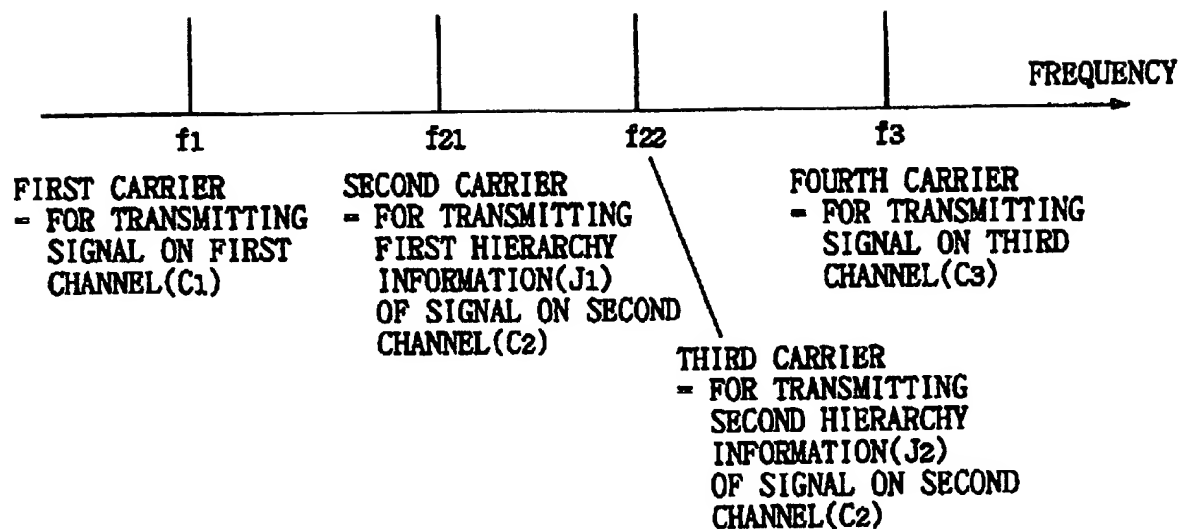




FIG. 12 PRIOR ART



# OPTICAL TRANSMITTER AND OPTICAL TRANSMISSION SYSTEM USING THE SAME

## BACKGROUND OF THE INVENTION

### 1. Field of the Invention

The present invention relates to an optical transmission system, and more particularly, to a system for optically transmitting a digital modulation signal obtained by frequency-multiplexing.

### 2. Description of the Prior Art

FIG. 9 is a diagram showing a first example of a conventional optical transmission system. In FIG. 9, the optical transmission system includes an analog-to-digital converting portion 901, a digital modulating circuit 903, an electrical-optical converting portion 905, an optical transmission channel 906, an optical-electrical converting portion 907, a transmission channel 908, a demodulating portion 9100, and a digital-to-analog converting portion 913. The demodulating portion 9100 includes a filter 910 and a digital demodulating circuit 911.

Description is now made of operations of the conventional optical transmission system shown in FIG. 9. The analog-to-digital converting portion 901 samples and quantizes an analog signal, such as an image signal, and converts the sampled and quantized analog signal into a digital signal. The digital modulating circuit 903 converts the digital signal into a digital modulation signal by a predetermined digital modulation system using a carrier having a predetermined frequency  $f_0$ , and outputs the digital modulation signal. The digital modulation signal is converted into an optical signal in the electrical-optical converting portion 905, and the optical signal is transmitted by the optical transmission channel 906, and is then reconverted into an electrical signal in the optical-electrical converting portion 907. In the demodulating portion 9100, the digital modulation signal, having the frequency  $f_0$  and which was passed through the filter 910, is converted into a digital signal by the digital demodulating circuit 911. The digital-to-analog converting portion 913 reconverts the digital signal into an analog signal. Examples of the above-mentioned predetermined digital modulation system include a 16 QAM modulation system. In this case, it is generally possible to ensure a transmission capacity of several tens of megabytes per second.

FIG. 10 is a diagram showing a second example of a conventional optical transmission system. In FIG. 10, the optical transmission system includes an analog-to-digital converting portion 901, a dividing portion 1002, a modulating portion 1003, a multiplexing portion 1004, an electrical-optical converting portion 905, an optical transmission channel 906, an optical-electrical converting portion 907, a transmission channel 908, a branching portion 1009, a demodulating portion 1010, a synthesizing portion 1012, and a digital-to-analog converting portion 913. The modulating portion 1003 includes a first digital modulating circuit 10031 and a second digital modulating circuit 10032. The demodulating portion 1010 includes a first filter 10101, a second filter 10102, a first digital demodulating circuit 10111, and a second digital demodulating circuit 10112.

Description is now made of operations of the conventional optical transmission system shown in FIG. 10. This example illustrates a construction in a case where the transmission rate is higher than that in the above-mentioned first conventional system. In this example, two carriers having predetermined frequencies  $f_1$  and  $f_2$ , which differ from each other, are used to transmit one signal. Specifically,

the dividing portion 1002 divides a digital signal, after analog-to-digital conversion, into two groups of digital information (first digital information  $J_1$  and second digital information  $J_2$ ) in accordance with a predetermined dividing method. The first digital modulating circuit 10031 and the second digital modulating circuit 10032 in the modulating portion 1003 respectively convert the two groups of digital information, obtained by the division, into digital modulation signals using two independent carriers, having frequencies  $f_1$  and  $f_2$ . The multiplexing portion 1004 frequency-multiplexes the digital modulation signals to obtain one signal.

The signal transmitted through the electrical-optical converting portion 905, the optical transmission channel 906, the optical-electrical converting portion 907, and the transmission channel 908 is branched into two signals in the branching portion 1009, after which the signals are respectively inputted to the first filter 10101 and the second filter 10102 in the demodulating portion 1010. The first digital demodulating circuit 10111 demodulates the first digital modulation signal (having the frequency  $f_1$ ) which was passed through the first filter 10101 to yield the first digital information  $J_1$ . Likewise, the second digital demodulating circuit 10112 demodulates the second digital modulation signal (having the frequency  $f_2$ ) which was passed through the second filter 10102 to yield the second digital information  $J_2$ . The synthesizing portion 1012 synthesizes the first and second digital information  $J_1$  and  $J_2$  in accordance with a process which is reverse to the above-mentioned predetermined dividing method used in the dividing portion 1002, to reproduce a digital signal. Examples of the predetermined dividing method include a method of dividing a digital signal into two groups of digital information every other sample. As described in the first conventional example, there is a limit on the capacity of the digital modulation signal which can be transmitted by one carrier. In this example, therefore, a digital signal, which is to be transmitted, is divided into a plurality of (two in FIG. 10) groups of information, and the groups of information are respectively converted into digital modulation signals using independent carriers. The digital modulation signals are frequency-multiplexed and are together optically transmitted together, thus ensuring a higher transmission rate (which is twice that in the first conventional example).

FIG. 11 is a diagram showing a third example of a conventional optical transmission system. In FIG. 11, the optical transmission system includes first to third analog-to-digital converting portions 11011 to 11013, a dividing portion 1102, first to third modulating portions 11031 to 11033, a channel multiplexing portion 1104, an electrical-optical converting portion 905, an optical transmission channel 906, an optical-electrical converting portion 907, a transmission channel 908, a channel branching portion 1109, first to third demodulating portions 11101 to 11103, a synthesizing portion 1112, and first to third digital-to-analog converting portions 11131 to 11133.

Description is now made of operations of the conventional optical transmission system shown in FIG. 11. The above-mentioned first and second conventional systems are for transmission on one channel, while the third conventional system is for transmission on a plurality of channels (three channels in FIG. 11). In this conventional example, signals on three channels  $C_1$ ,  $C_2$  and  $C_3$  are subjected to digital modulation using carriers having different frequencies  $f_1$ ,  $f_{21}$ ,  $f_{22}$  and  $f_3$  which are previously assigned. The modulated signals are frequency-multiplexed and are optically transmitted together, as shown in FIG. 12, for example.

In this third conventional example, therefore, an analog-to-digital converting portion, a modulating portion, a demodulating portion, and a digital-to-analog converting portion are provided so as to correspond to each of the three transmission signals  $C_1$ ,  $C_2$  and  $C_3$ . The channel multiplexing portion 1104 frequency-multiplexes digital modulation signals outputted from all the modulating portions 11031 to 11033. The channel branching portion 1109 branches a signal, which is obtained by the frequency-multiplexing and which is optically transmitted through the electrical-optical converting portion 905 to the transmission channel 908, and respectively inputs signals obtained by the branching to all the demodulating portions 11101 to 11103. In FIG. 11, only the signal on the second channel  $C_2$  requires a high transmission rate. Therefore, the dividing portion 1102 and the synthesizing portion 1112 are provided on the second channel, and transmission is made using the two carriers (having the frequencies  $f_{21}$  and  $f_{22}$ ). Detailed operations of components are the same as those in the first and second conventional examples and hence, the detailed description thereof is omitted.

A system using an analog SCM (Sub-Carrier Multiplex) transmission technique for optically transmitting a signal obtained by frequency-multiplexing using a plurality of carriers as described above is effective as a system capable of easily transmitting information at a high bit rate and on multi-channels. However, a transmission system (including an electrical-optical converting portion, an optical transmission channel, an optical-electrical converting portion, and a transmission channel) generally has frequency characteristics which make it difficult to obtain transmission qualities which are equal and uniform over the entire transmission band. For example, a light source for direct modulation (a semiconductor laser) used for an electrical-optical converting portion exhibits a larger amount of waveform distortion at higher modulation frequencies. This characteristic is due to the effect of the laser's relaxation oscillation frequency. Therefore, degradation of the waveform of a digital modulation signal having a high carrier frequency is larger than degradation of the waveform of a digital modulation signal having a low carrier frequency, whereby the transmission quality such as BER (a bit error rate) is degraded. Further, when the number of transmission channels is large, second order distortion is large in the vicinity of the center of the transmission band, while third order distortion is large in the upper and lower parts of the transmission band.

In the conventional optical transmission system for transmitting a plurality of digital modulation signals using the analog SCM transmission technique as described above, the degree of degradation of the waveform of a transmission signal or the magnitude of distortion thereof differs depending on the carrier frequency, whereby there arises a difference in transmission quality among channels.

The above-mentioned problems not only arise in when an analog signal is converted into a digital signal and the digital signal is transmitted, but also when digital data is multiplexed and optically transmitted.

#### SUMMARY OF THE INVENTION

Therefore, an object of the present invention is to provide an optical transmission system and an optical transmission apparatus capable of minimizing the effect of irregularities of transmission characteristics in the entire transmission band on received and reproduced information and to avoid differences in signal quality among channels.

Another object of the present invention is to provide an optical transmission system and an optical transmission

apparatus capable of keeping the quality of a signal reproduced on a receiving side as good as possible even when all information on all channels cannot be transmitted or received.

In order to attain the above-mentioned objects, the present invention has the following characteristics.

A first aspect of the present invention is directed to an optical transmission system for optically transmitting a digital modulation signal obtained by frequency-multiplexing. The system includes a hierarchy separating portion for dividing a digital signal into  $n$  digital signals according to an  $n$  level hierarchy ( $n$  is a natural number of not less than two). The signal is divided on the basis of the degree of importance of aspects of the signal in constructing the original data. The division is accomplished in accordance with a predetermined hierarchical system. The digital signals are output as first to  $n$ th digital information arranged in descending order of degrees of importance. A modulating portion digitally modulates first to  $n$ th carriers having different frequencies. The first to  $n$ th carriers are assigned to the first to  $n$ th digital information respectively. The first to  $n$ th carriers are modulated with the first to  $n$ th digital information respectively. The modulating portion then outputs the first to  $n$ th digital modulation signals. A multiplexing portion frequency-multiplexes the first to  $n$ th digital modulation signals which are output from the modulating portion. An electrical-optical converting portion converts an electrical signal, which is output from the multiplexing portion, into an optical signal. An optical transmission channel transmits the optical signal which is output from the electrical-optical converting portion. An optical-electrical converting portion reconverts the optical signal, which is transmitted by the optical transmission channel, into an electrical signal. The electrical signal, which is output from the optical-electrical converting portion is transmitted through a transmission channel. A branching portion branches the electrical signal, which is transmitted through the transmission channel, into  $m$  ( $m$  is a natural number satisfying  $1 \leq m \leq n$ ) electrical signals. A demodulating portion demodulates the  $m$  electrical signals, which are output from the branching portion and outputs first to  $m$ th digital information selected out of the first to  $n$ th digital information. A hierarchy synthesizing portion, to which the first to  $m$  digital information are inputted, synthesizes the digital information to form a digital signal in accordance with a process reverse to that in the predetermined hierarchical system. The hierarchy synthesizing portion then outputs the digital signal. As described in the foregoing first aspect, the digital signal to be transmitted is divided into a plurality of levels of digital information within a hierarchy depending on degrees of importance in constructing the original data. The carriers having different frequencies which are respectively assigned to the hierarchy levels are digitally modulated by the respective digital information, and all the digital modulation signals are frequency-multiplexed and are together optically transmitted. Further, the respective digital modulation signals are demodulated with respect to the electrical signal obtained by reversion after the optical transmission, and the respective groups of digital information are synthesized, to reproduce the original digital signal.

According to the first aspect, therefore, transmission information can be subjected to various operations or transmission control depending on degrees of importance in constructing a transmission signal. As a result, it is possible to realize an optical transmission system which is high in quality, low in cost and superior in the possibility of development.

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A second aspect of the present invention is characterized in that in the first aspect, when  $n > m$ , the demodulating portion respectively demodulates the  $m$  electrical signals output from the branching portion and outputs the first to  $m$ th digital information selected in descending order of degrees of importance out of the first to  $n$ th digital information.

When the capacity of an optical transmission channel is small, and the capability of a receiver is low, digital information of all hierarchies cannot, in some cases, be transmitted or received. In such a case, in the second aspect, the information having a high degree of importance is transmitted or received by priority, in order to minimize the effect on reproduced data.

A third aspect of the present invention is characterized in that in the first aspect, in the entire transmission band of a transmission line (which includes the electrical-optical converting portion, the optical transmission channel, the optical-electrical converting portion and the transmission channel), the carrier which is assigned to the digital information having a higher degree of importance out of the first to  $n$ th carriers is arranged in a band whose transmission characteristics are better, and the carrier which is assigned to the digital information having a lower degree of importance is arranged in a band whose transmission characteristics are worse.

As described in the foregoing, when a signal obtained by frequency-multiplexing is transmitted using an optical transmission channel, the degree of degradation of the waveform of the signal or the magnitude of distortion thereof differs depending on bands used. In the third aspect, therefore, the information of the hierarchy having a high degree of importance is transmitted in a band whose transmission characteristics are good, and the information of the hierarchy having a low degree of importance is transmitted in a band whose transmission characteristics are bad, so as to minimize the effect of the degradation and the distortion caused at the time of transmission on data reproduced on the receiving side. Consequently, high-quality transmission is possible.

A fourth aspect of the present invention is characterized in that in the third aspect, the digital signal is a digital signal having  $w$  bits ( $w$  is a natural number not less than  $n$ ). The hierarchy separating portion divides the digital signal having the  $w$  bits into first to  $n$ th digital information such that the first to  $n$ th digital information include one or more of the  $w$  bits and such that the first to  $n$ th digital information are arranged in the order from the most significant bit to the least significant bit. The carrier which is assigned to the digital information to which the bit closest to the most significant bit belongs is arranged in a band whose transmission characteristics are better, and the carrier which is assigned to the digital information to which the bit closest to the least significant bit belongs is arranged in a band whose transmission characteristics are worse in the entire transmission band of the optical transmission line.

As described in the foregoing, in the fourth aspect, the digital signal having a plurality of bits is hierarchically divided every one or more bits into the first to  $n$ th digital information. The high order bit digital information having a high degree of importance in constructing data is transmitted in a band whose transmission characteristics are good, and the low order bit digital information having a low degree of importance in constructing data is transmitted in a band whose transmission characteristics are bad. Consequently, high-quality transmission is possible.

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A fifth aspect of the present invention is characterized in that in the third aspect, the hierarchy separating portion subjects the digital signal to predetermined time/frequency conversion and divides the digital signal into first to  $n$ th digital information in the order from a lowest frequency component, i.e., a component near a DC component, to the highest frequency component. The carrier which is assigned to the digital information to which a component close to the DC component belongs is arranged in a band whose transmission characteristics are better, and the carrier which is assigned to the digital information to which a component close to the highest frequency component belongs is arranged in a band whose transmission characteristics are worse in the entire transmission band of the optical transmission channel.

As described in the foregoing, in the fifth aspect, the digital signal is subjected to predetermined time/frequency conversion, and the digital signal is divided into first to  $n$ th digital information in the order from a lowest frequency component to a highest frequency component. The digital information having a high degree of importance in constructing the data, i.e., the digital information to which a component close to the DC component belongs, is transmitted in a band whose transmission characteristics are good, and the digital information having a low degree of importance in constructing data, i.e., the digital information to which a component close to the highest frequency component belongs, is transmitted in a band whose transmission characteristics are bad. Consequently, high-quality transmission is possible.

A sixth aspect of the present invention is characterized in that, in the fifth aspect, the hierarchy separating portion subjects the digital signal to Fourier transform as the predetermined time/frequency conversion.

A seventh aspect of the present invention is characterized in that, in the fifth aspect, the hierarchy separating portion subjects the digital signal to discrete cosine transform (DCT) as the predetermined time/frequency conversion.

An eighth aspect of the present invention is characterized in that, in the third aspect, the band whose transmission characteristics are better is a lower frequency band, and the band whose transmission characteristics are worse is a higher frequency band in the entire transmission band of the transmission line.

As described in the foregoing, generally in an optical transmission system, the waveform of a digital modulation signal having a high carrier frequency is greatly degraded. In the eighth aspect, therefore, the low frequency band is used as a band where digital information having a high degree of importance is to be transmitted, and the high frequency band is used as a band where digital information having a low degree of importance is to be transmitted.

When degradation of the waveform caused by distortion of a particular degree is taken up as a problem, a band whose transmission characteristics are bad is not necessarily located in a high band. Bands other than the high band may, in some cases, be used in order to transmit digital information having a low degree of importance. For example, third order distortion higher in an intermediate band in the entire transmission band. When degradation of the waveform caused by the third order distortion is a problem, the digital information having a low degree of importance is transmitted using the intermediate band. On the other hand, second order distortion is higher in a high band and a low band in the entire transmission band. When degradation of the waveform caused by the second order distortion is a

problem, the digital information having a low degree of importance is transmitted using the high band or the low band.

A ninth aspect of the present invention is characterized in that in the first aspect,  $p$  sets of elements are provided and each set includes a hierarchy separating portion, a demodulating portion, and a hierarchy synthesizing portion. The  $p$  sets of elements correspond to digital signals on  $p$  channels respectively ( $p$  is a natural number of not less than two). The multiplexing portion frequency-multiplexes all digital modulation signals which are output from the  $p$  sets of modulating portions, and the branching portion branches the electrical signal transmitted by the transmission channel and inputs electrical signals obtained as a result of the branching into the  $p$  sets of demodulating portions. In this way, the digital signals on the  $p$  channels are frequency-multiplexed and are together optically transmitted.

As described in the foregoing, in the ninth aspect, the  $p$  sets of hierarchy separating portions, modulating portions, demodulating portions and hierarchy synthesizing portions are provided, to frequency-multiplex and together optically transmit the digital signals on the  $p$  channels. Consequently, the transmission capability is further increased.

A tenth aspect of the present invention is characterized by further including, in the ninth aspect, an optical branching portion arranged on the optical transmission channel for branching the optical signal into  $q$  ( $q$  is a natural number of not less than two) optical signals, and  $q$  optical receiving sets. Each of the  $q$  receiving sets includes an optical-electrical converting portion, a transmission channel, and a branching portion. Also,  $p$  sets of demodulating portions and  $p$  sets of hierarchy synthesizing portions are provided so as to correspond to the  $q$  optical signals obtained as a result of the branching in the optical branching portion.

As described in the foregoing, in the tenth aspect, the optical signal on the optical transmission channel is divided into  $q$  optical signals, thereby to make it possible to simultaneously distribute the  $q$  optical signals among a plurality of receivers.

An eleventh aspect of the present invention is characterized in that, in the tenth aspect, the condition of  $n > m$  holds in at least one of the  $q$  optical receiving sets. That is, in the one optical receiving set, the digital information of all the hierarchies cannot be demodulated for reasons such as lack of the receiving capability. Therefore, the digital information of the hierarchy having a high degree of importance is demodulated, thereby to obtain reproduced data which is as high in quality as possible.

A twelfth aspect of the present invention is characterized by further including, in the ninth aspect, an electrical distributing portion for branching an output signal from the optical-electrical converting portion into  $t$  ( $t$  is a natural number of not less than two) electrical signals, and  $t$  optical receiving sets. Each of the  $t$  optical receiving sets includes a transmission channel, and a branching portion. Also,  $p$  sets of demodulating portions, and  $p$  sets of hierarchy synthesizing portions are provided so as to correspond to the  $t$  electrical signals obtained as a result of the branching in the electrical distributing portion.

As described in the foregoing, in the twelfth aspect, the output signal from the optical-electrical converting portion is branched into  $t$  electrical signals, thereby to make it possible to simultaneously distribute the  $t$  electrical signals among a plurality of receivers.

A thirteenth aspect of the present invention is characterized in that, in the twelfth aspect, the condition of  $n > m$  holds

in at least one of the  $t$  optical receiving sets. That is, in the one optical receiving set, the digital information of all the hierarchies cannot be demodulated for reasons such as lack of the receiving capability. Therefore, the digital information of the hierarchy having a high degree of importance is demodulated, thereby to obtain reproduced data which is as high in quality as possible.

A fourteenth aspect of the present invention is characterized in that, in the ninth aspect, the entire transmission band of the transmission line (which includes the electrical-optical converting portion, the optical transmission channel, the optical-electrical converting portion and the transmission channel) is divided into first to  $n$ th information transmission bands from a low band to a high band,  $p$  carriers having different frequencies are set in each of the bands, and the first to  $n$ th carriers, which are respectively assigned to the digital signals on the  $p$  channels, are picked up one at a time from the carriers in the first to  $n$ th information transmission bands.

As described in the foregoing, in the fourteenth aspect, when the digital signals on the  $p$  channels are simultaneously optically transmitted, the entire transmission band of the optical transmission channel is divided into first to  $n$ th information transmission bands from a low band to a high band, and the  $p$  carriers having different frequencies are respectively set in each of the bands. The first to  $n$ th carriers which are respectively assigned to the digital signals on the  $p$  channels are picked up one at a time from the carriers in the first to  $n$ th information transmission bands.

A fifteenth aspect of the present invention is characterized by further including, in the first aspect, an analog-to-digital converting portion for converting an analog signal into a digital signal and for inputting the digital signal to the hierarchy separating portion, and a digital-to-analog converting portion for reconverting the digital signal output from the hierarchy synthesizing portion into an analog signal.

As described in the foregoing, in the fifteenth aspect, the analog signal such as an image signal or a voice signal is converted into the digital signal, after which the digital signal is optically transmitted.

A sixteenth aspect of the present invention is directed to an optical transmission apparatus for converting a digital modulation signal obtained by frequency-multiplexing into an optical signal and transmitting the optical signal onto an optical transmission channel, which includes a hierarchy separating portion for dividing a fed digital signal into digital signals in  $n$  ( $n$  is a natural number of not less than two) hierarchies depending on degrees of importance in constructing the original data in accordance with a predetermined hierarchical system and outputting the digital signals in the  $n$  hierarchies as first to  $n$ th digital information arranged in descending order of degrees of importance. A modulating portion digitally modulates first to  $n$ th carriers having different frequencies which are respectively assigned to the first to  $n$ th digital information by the digital information and for outputting first to  $n$ th digital modulation signals. A multiplexing portion frequency-multiplexes the first to  $n$ th digital modulation signals output from the modulating portion. An electrical-optical converting portion converts an electrical signal output from the multiplexing portion into an optical signal and sends out the optical signal onto the optical transmission channel.

As described in the foregoing, in the sixteenth aspect, the digital signal to be transmitted is converted into a digital signal, after which the digital signal is divided into digital

information of a plurality of hierarchies depending on degrees of importance in constructing the original data. The carriers having different frequencies which are assigned every hierarchies are digitally modulated by the digital information, and all the digital modulation signals are frequency-multiplexed and are together optically transmitted.

According to the sixteenth aspect, therefore, transmission information can be subjected to various operations or transmission control depending on degrees of importance in constructing a transmission signal. As a result, it is possible to realize an optical transmission system which is high in quality, low in cost, and superior in the possibility of development.

The foregoing and other objects, features, aspects and advantages of the present invention will become more apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram showing the construction of an optical transmission system according to a first embodiment of the present invention;

FIG. 2 is a diagram showing one example of the frequency arrangement of carriers for digital modulation in the optical transmission system according to the first embodiment of the present invention;

FIG. 3 is a block diagram showing the construction of an optical transmission system according to a second embodiment of the present invention;

FIG. 4 is a block diagram showing the construction of an optical transmission system according to a third embodiment of the present invention;

FIG. 5 is a diagram showing one example of the frequency arrangement of carriers for digital modulation in the optical transmission system according to the third embodiment of the present invention;

FIGS. 6A and 6B illustrate a block diagram showing the construction of an optical transmission system according to a fourth embodiment of the present invention;

FIG. 7 is a diagram showing one example of the transmission band arrangement which can be used in the optical transmission system according to the fourth embodiment of the present invention;

FIGS. 8A and 8B illustrate a block diagram showing the construction of an optical transmission system according to a fifth embodiment of the present invention;

FIG. 9 is a block diagram showing a first example of a conventional optical transmission system;

FIG. 10 is a block diagram showing a second example of the conventional optical transmission system;

FIG. 11 is a block diagram showing a third example of the conventional optical transmission system; and

FIG. 12 is a diagram showing one example of the frequency arrangement of carriers for digital modulation in the third example of the conventional optical transmission system.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

##### (1) First Embodiment

FIG. 1 is a diagram showing the construction of an optical transmission system according to a first embodiment of the

present invention. In FIG. 1, the optical transmission system includes an analog-to-digital converting portion 101, a hierarchy separating portion 102, a modulating portion 103, a multiplexing portion 104, an electrical-optical converting portion 105, an optical transmission channel 106, an optical-electrical converting portion 107, a transmission channel 108, a branching portion 109, a demodulating portion 110, a hierarchy synthesizing portion 112, and a digital-to-analog converting portion 113. The modulating portion 103 includes first to fourth digital modulating circuits 1031 to 1034, and the demodulating portion 110 includes first to fourth filters 1101 to 1104 and first to fourth digital demodulating circuits 1111 to 1114.

Description is now made of operations of the optical transmission system according to the first embodiment. The analog-to-digital converting portion 101 samples and quantizes an analog signal, such as an image signal, and converts the analog signal into a digital signal. The hierarchy separating portion 102 divides the digital signal into a plurality of groups of digital information depending on degrees of importance in constructing the original analog signal in accordance with a predetermined hierarchical system. In FIG. 1, the digital signal is divided into four groups of information,  $D_1$  to  $D_4$ . In the modulating portion 103, the first to fourth digital modulating circuits 1031 to 1034 are respectively provided so as to correspond to the first to fourth groups of digital information  $D_1$  to  $D_4$ . The first to fourth digital modulating circuits 1031 to 1034 respectively convert the groups of digital information into digital modulation signals using four carriers having different frequencies  $f_1$ ,  $f_2$ ,  $f_3$  and  $f_4$  and output the digital modulation signals. For example, the first digital modulating circuit 1031 uses the carrier having the frequency  $f_1$ , to convert the first group of digital information  $D_1$  into a digital modulation signal. An example of the frequency arrangement of the first to fourth carriers is illustrated in FIG. 2. Specifically, in the present embodiment, the frequency  $f_1$  of the carrier used for transmitting the first group of digital information  $D_1$  having the highest degree of importance is arranged on the lowest frequency side, and the frequency  $f_4$  of the carrier used for transmitting the fourth group of digital information  $D_4$  having the lowest degree of importance is arranged on the highest frequency side.

The multiplexing portion 104 frequency-multiplexes all the digital modulation signals outputted from the first to fourth digital modulating circuits 1031 to 1034. A digital modulation signal obtained as a result of the frequency-multiplexing is converted into an optical signal by the electrical-optical converting portion 105. The optical signal is then transmitted through the optical transmission channel 106. The optical-electrical converting portion 107 reconverts the transmitted optical signal into an electrical signal. The electrical signal obtained as a result of the reversion is transmitted through the transmission channel 108, and is branched into four electrical signals by the branching portion 109. After the signal is branched, the four electrical signals are respectively input into the first to fourth filters 1101 to 1104 in the demodulating portion 110. The first to fourth filters 1101 to 1104 and the first to fourth digital demodulating circuits 1111 to 1114 are provided so as to correspond to the first to fourth groups of digital information  $D_1$  to  $D_4$  respectively, and pass only the respective digital modulation signals and output the respective groups of digital information. For example, the first digital demodulating circuit 1111 demodulates the first group of digital information  $D_1$ , and outputs the demodulated information. The hierarchy synthesizing portion 112 synthesizes the first

to fourth groups of digital information  $D_1$  to  $D_4$  to make one digital signal in accordance with a process reverse to that in the above-mentioned predetermined hierarchical system. The digital-to-analog converting portion 113 subjects an output of the hierarchy synthesizing portion 112 to digital-to-analog conversion, to reproduce an analog signal. One way to accomplish the above-mentioned predetermined hierarchical system is to divide the digital signal into groups of bits and to arrange the groups according to significance. When the number of quantized bits composing a digital signal is "8", and the quantized bits are taken as  $b_1$  (LSB: Least Significant Bit),  $b_2$ ,  $b_3$ ,  $b_4$ ,  $b_5$ ,  $b_6$ ,  $b_7$ , and  $b_8$  (MSB: Most Significant Bit) in ascending order, the quantized bits can be grouped such that each group includes two bits as follows. The two bits  $b_8$  and  $b_7$  in the vicinity of the MSB are put in a first group of digital information, the two bits  $b_6$  and  $b_5$  are put in a second group of digital information, the two bits  $b_4$  and  $b_3$  are put in a third group of digital information, and the two bits  $b_2$  and  $b_1$  in the vicinity of the LSB are put in a fourth group of digital information. Another way to accomplish the hierarchical system is to convert the digital signal into a frequency representation using a predetermined time/frequency conversion method and dividing the frequency components of the frequency representation into four groups. The lowest frequency component, i.e., the information in the vicinity of a DC component, is put in the first group of digital information and the highest frequency component is put in the fourth group of digital information. Examples of the predetermined time/frequency conversion include Fourier transform and discrete cosine transform (DCT).

## (2) Second Embodiment

FIG. 3 is a diagram showing the construction of an optical transmission system according to a second embodiment of the present invention. In FIG. 3, the optical transmission system includes an analog-to-digital converting portion 101, a hierarchy separating portion 102, a modulating portion 103, a multiplexing portion 104, an electrical-optical converting portion 105, an optical transmission channel 106, an optical-electrical converting portion 107, a transmission channel 108, a branching portion 109, a demodulating portion 110, a hierarchy synthesizing portion 112, and a digital-to-analog converting portion 113. The modulating portion 103 includes first to fourth digital modulating circuits 1031 to 1034. Further, the demodulating portion 110 includes first to third filters 1101 to 1103 and first to third digital demodulating circuits 1111 to 1113.

Description is now made of operations of the optical transmission system according to the second embodiment. Detailed operations of respective components are the same as those in the first embodiment and therefore, only the operations characteristic to the second embodiment will be described. The present embodiment illustrates a system in which a receiver need not receive a high-quality signal or a system in which the receiver cannot receive the high-quality signal. Specifically, the branching portion 109 branches a signal outputted from the transmission channel 108 into three signals, and respectively inputs the signals to the first to third filters 1101 to 1103 in the demodulating portion 110. The first to third filters 1101 to 1103 and the first to third digital demodulating circuits 1111 to 1113 are provided so as to correspond to first to third groups of digital information  $D_1$  to  $D_3$ , respectively and demodulate and convert the respective digital modulation signals to the digital information and output the digital information. Consequently, on the receiving side, the fourth group of digital information  $D_4$  is not reproduced. The hierarchy synthesizing portion 112

synthesizes only the first to third groups of digital information  $D_1$  to  $D_3$  to make a digital signal without using the fourth group of digital information  $D_4$ , and outputs the digital signal. A receiver might not receive the high-quality signal when, for example, the transmittable bandwidth of the transmission channel 108 is narrow, thus preventing the digital modulation signal of the fourth group of digital information  $D_4$  from being transmitted.

## (3) Third Embodiment

FIG. 4 is a diagram showing the construction of an optical transmission system according to a third embodiment of the present invention. In FIG. 4, the optical transmission system includes first to third analog-to-digital converting portions 4011 to 4013, first to third hierarchy separating portions 4021 to 4023, first to third modulating portions 4031 to 4033, a channel multiplexing portion 404, an electrical-optical converting portion 405, an optical transmission channel 406, an optical-electrical converting portion 407, a transmission channel 408, a channel branching portion 409, first to third demodulating portions 4101 to 4103, first to third hierarchy synthesizing portions 4121 to 4123, and first to third digital-to-analog converting portions 4131 to 4133. Each of the modulating portions includes four digital modulating circuits, and each of the demodulating portions includes four sets of filters and digital demodulating circuits.

Description is now made of operations of the optical transmission system according to the third embodiment. The present embodiment illustrates a system in which the above-mentioned first embodiment is enlarged to accomplish transmission on multi-channels (three channels in FIG. 4:  $C_1$ ,  $C_2$ , and  $C_3$ ). For example, the signal on the first channel  $C_1$  is converted into a digital signal by the first analog-to-digital converting portion 4011, after which the digital signal is divided into four groups of digital information  $D_{11}$  to  $D_{14}$  which differ in degrees of importance by the first hierarchy separating portion 4021, and the four groups of digital information are respectively converted into digital modulation signals using four carriers having different frequencies  $f_{11}$  to  $f_{14}$  in the first modulating portion 4031.

FIG. 5 illustrates one example of the frequency arrangement of the four carriers which are assigned to each of the signals on the first to third channels. As shown in FIG. 5, out of the first to fourth carriers corresponding to the signal on each of the channels, the carrier used for the transmission of the digital information having a higher degree of importance is arranged on a lower frequency side of the frequency spectrum, and the carrier used for the transmission of digital information having a lower degree of importance is arranged on a higher frequency side of the frequency spectrum. Further, the entire transmission band is divided into first to fourth information transmission bands from a low frequency band to a high frequency band. All the first carriers, all the second carriers, all the third carriers, and all the fourth carriers corresponding to the signals on all the channels are arranged in the first information transmission band, the second information transmission band, the third information transmission band, and the fourth information transmission band respectively. Although in the present embodiment, the entire transmission band is divided into the four information transmission bands so that a signal in any one of hierarchies on all the channels is included in each of the information transmission bands, the degrees of importance of all information of the hierarchies on all the channels are assigned by a same standard so that the carriers are arranged on the frequency axis in accordance with the priorities without providing such information transmission bands.

The channel multiplexing portion 404 frequency-multiplexes all the digital modulation signals outputted from



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all the modulating portions 4031 to 4033. A signal obtained as a result of the frequency-multiplexing is transmitted through the electrical-optical converting portion 405 to the transmission channel 408, and is then branched into three signals in the channel branching portion 409. The signals are then input into the first to third demodulating portions 4101 to 4103 respectively. The first to third demodulating portions are provided so as to correspond to the signals on the respective channels. For example, in the first demodulating portion 4101, only four digital modulation signals having frequencies  $f_{11}$ ,  $f_{12}$ ,  $f_{13}$  and  $f_{14}$  corresponding to the signal on the first channel  $C_1$  are passed, demodulated, and outputted as four groups of digital information  $D_{11}$ ,  $D_{12}$ ,  $D_{13}$  and  $D_{14}$ . The four groups of digital information are synthesized to make one digital signal by the first hierarchy synthesizing portion 4121. The digital signal is reconverted into an analog signal by the first digital-to-analog converting portion 4131, and the analog signal is outputted.

## (4) Fourth Embodiment

FIGS. 6A and 6B illustrate a diagram showing the construction of an optical transmission system according to a fourth embodiment of the present invention. In FIGS. 6A and 6B, the optical transmission system includes first to third analog-to-digital converting portions 4011 to 4013, first to third hierarchy separating portions 4021 to 4023, first to third modulating portions 4031 to 4033, a channel multiplexing portion 404, an electrical-optical converting portion 405, an optical transmission channel 406, a light distributing portion 600, first and second optical-electrical converting portions 6071 to 6072, first and second transmission channels 6081 and 6082, first and second channel branching portions 6091 and 6092, first to sixth demodulating portions 6101 to 6106, first to sixth hierarchy synthesizing portions 6121 to 6126, and first to sixth digital-to-analog converting portions 6131 to 6136. As in the above-mentioned first to third embodiments, each of the modulating portions includes four digital modulating circuits, and each of the demodulating portions includes four sets of filters and digital demodulating circuits.

Description is now made of operations of the optical transmission system according to the fourth embodiment. The present embodiment illustrates construction in which the third embodiment is adapted to a case where the number of receivers (or optical-electrical converting portions) is plural (two in FIGS. 6A and 6B). Each of the signals on first to third channels  $C_1$  to  $C_3$  is divided into groups of digital information of four hierarchies, after which the groups of digital information are converted into respective digital modulation signals, and the digital modulation signals are frequency-multiplexed. A signal obtained as a result of the frequency-multiplexing is converted into an optical signal, and the optical signal is transmitted through the optical transmission channel 406. The optical signal is branched into two optical signals by the optical branching portion 600, after which the optical signals are input into the first and second optical-electrical converting portions 6071 and 6072 respectively. For example, the first optical-electrical converting portion 6071 reconverts the received optical signal into an electrical signal. The electrical signal obtained as a result of the reversion is transmitted through the first transmission channel 6081, and is then branched into three electrical signals by the first channel branching portion 6091. The three electrical signals are respectively input into the three demodulating portions of a first receiver, i.e., the first to third demodulating portions 6101 to 6103. For example, four groups of digital information  $D_{11}$ ,  $D_{12}$ ,  $D_{13}$  and  $D_{14}$  corresponding to the signal on the first channel  $C_1$ ,

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which is demodulated in the first demodulating portion 6101, are synthesized to make one digital signal by the first hierarchy synthesizing portion 6121, and the digital signal is reconverted into an analog signal by the first digital-to-analog converting portion 6131.

Each of the demodulating portions, each of the hierarchy synthesizing portions, and each of the digital-to-analog converting portions of a second receiver carry out demodulation, synthesis and digital-to-analog conversion depending on the signal quality required by the second receiver or the transmittable bandwidth or the like, as in the second embodiment. For example, as shown in FIG. 7, when the transmittable bandwidth of the second transmission channel 6082 is narrow, only the first to third groups of digital information corresponding to each of the signals on the channels (signals transmitted by first to third carriers which are arranged in the first to third information transmission bands) are demodulated to reproduce an analog signal on the receiving side.

## (5) Fifth Embodiment

FIGS. 8A and 8B illustrate a diagram showing the construction of an optical transmission system according to a fifth embodiment of the present invention. In FIGS. 8A and 8B, the optical transmission system includes first to third analog-to-digital converting portions 4011 to 4013, first to third hierarchy separating portions 4021 to 4023, first to third modulating portions 4031 to 4033, a channel multiplexing portion 404, an electrical-optical converting portion 405, an optical transmission channel 406, an optical-electrical converting portion 407, an electrical distributing portion 800, first and second transmission channels 6081 and 6082, first and second channel branching portions 6091 and 6092, first to sixth demodulating portions 6101 to 6106, first to sixth hierarchy synthesizing portions 6121 to 6126, and first to sixth digital-to-analog converting portions 6131 to 6136. As in the above-mentioned first to fourth embodiments, each of the modulating portions includes four digital modulating circuits, and each of the demodulating portions includes four sets of filters and digital demodulating circuits.

Description is now made of operations of the optical transmission system according to the fifth embodiment. The present embodiment illustrates a construction in which the third embodiment is adapted to a case where the number of receivers is two, similarly to the above-mentioned fourth embodiment. In the fifth embodiment however, a signal is branched into two signals at an electrical signal level, unlike the fourth embodiment in which a signal is branched into two signals in the state of an optical signal. Specifically, each of the signals on the first to third channels  $C_1$  to  $C_3$  is divided into groups of digital information of four hierarchies, after which the groups of digital information are converted into respective digital modulation signals, and the digital modulation signals are frequency-multiplexed. A signal obtained as a result of the frequency-multiplexing is converted into an optical signal, and the optical signal is transmitted through the optical transmission channel 406, after which the optical signal is reconverted into an electrical signal by the optical-electrical converting portion 407. The electrical signal is branched into two electrical signals by the electrical distributing portion 800, and the electrical signals are input into the channel branching portions of the first and second channel branching portions 6091 and 6092 respectively. The channel branching portion, the demodulating portion, the hierarchy synthesizing portion, and the digital-to-analog converting portion reproduce each of analog signals on the three channels  $C_1$ ,  $C_2$  and  $C_3$ , as in the fourth embodiment. Also,

as in the present embodiment, the amount of information to be transmitted is restricted by the transmittable bandwidth of the second transmission channel 6082. On the side of the second receiver, each of the analog signals is reproduced from only the first to third digital information transmitted by first to third information transmission bands.

Although in the above-mentioned embodiments, an analog signal is converted into a digital signal, after which the digital signal is hierarchically divided, multiplexed and optically transmitted, the present invention is also applicable when digital data is hierarchically divided, multiplexed and optically transmitted. Such a case, the analog-to-digital converting portion 101 and the digital-to-analog converting portion 113 are not required.

Further, in multi-channels transmission, digital signals on all channels may not be divided into the same numbers of hierarchies as those of channels. For example, in four channel transmission, the digital signals of three of the channels may be divided into four hierarchies respectively and transmitted, and the digital signal of the remaining channel may be divided into three hierarchies and transmitted.

As described in the prior art, generally in an optical transmission system, the waveform of a digital modulation signal having a high carrier frequency is greatly degraded. In each of the above-mentioned embodiments, therefore, a lower frequency band is used as a band where digital information having a higher degree of importance is to be transmitted, and a higher frequency band is used as a band where digital information having a lower degree of importance is to be transmitted. When degradation of the waveform caused by a particular order distortion is taken up as a problem on the multi-channel transmission, however, a frequency band whose transmission characteristics are not good does not necessarily exist in a higher frequency, whereby the other frequency bands may be used to transmit the digital information having a lower degree of importance in some cases. For example, third order distortion is increased in an intermediate band in the entire transmission band. When degradation of the waveform caused by the third order distortion is taken up as a problem, therefore, the digital information having a low degree of importance is transmitted using the intermediate band. On the other hand, second order distortion is increased in the high band and the low band in the entire transmission band. When degradation of the waveform caused by the second order distortion is a problem, the digital information having a low degree of importance is transmitted using the high band or the low band.

Although the present invention has been described and illustrated in detail, it is clearly understood that the same is by way of illustration and example only and is not to be taken by way of limitation, the spirit and scope of the present invention being limited only by the terms of the appended claims.

What is claimed is:

1. A method for transmitting information on a transmission medium, said method comprising:
  - arranging the information into a plurality of groups of information including a highest group and a lowest group, according to a hierarchy of importance, such that said highest group contains a portion of the information of a highest importance and said lowest group contains a portion of the information of a lowest importance; and
  - transmitting said plurality of groups through the transmission medium such that said highest group is trans-

mitted at a first frequency, at which a transmission characteristic of the transmission medium is of high quality, and said lowest-group is transmitted at a second frequency, at which the transmission characteristic of the transmission medium is of lower quality than at said first frequency.

2. A method for transmitting information as claimed in claim 1, wherein the information includes a plurality of bits ranging from a most significant bit to a least significant bit, the portion of the information of the highest importance includes the most significant bit, and the portion of the information of the lowest importance includes the least significant bit.

3. A method for transmitting information as claimed in claim 1, wherein the information includes a plurality of frequency components ranging from a lowest frequency component to a highest frequency component, the portion of the information of the highest importance includes the lowest frequency component, and the portion of the information of the lowest importance includes the highest frequency component.

4. A method for transmitting information as claimed in claim 1, further comprising:

receiving from the transmission medium at least said highest group of information.

5. A method of transmitting information as claimed in claim 4, further comprising receiving all of said plurality of groups of information except said lowest group.

6. A method of transmitting information as claimed in claim 4, further comprising reconstructing the information from said at least said highest group of information received from the transmission medium.

7. An optical transmission system comprising:

a hierarchy separating portion for receiving a digital signal which represents information, and for dividing the digital signal into n digital portion signals each of which includes a respective one of a plurality of portions of the digital signal, according to a hierarchy, such that a first to an nth digital portion signals are arranged according to decreasing degrees of importance of the respective portion, from a highest degree to an nth degree, wherein n is a number greater than or equal to two;

a modulating portion for receiving said n digital portion signals, and for digitally modulating n carriers with said n digital portion signals respectively to form n digital modulation signals respectively, said n carriers each having different frequencies;

a multiplexing portion for receiving said n digital modulation signals, and for frequency multiplexing said n digital modulation signals to form a first electrical signal;

an electrical-optical converting portion for receiving said first electrical signal, and for converting said first electrical signal into a corresponding optical signal;

an optical transmission channel for conveying said corresponding optical signal;

an optical-electrical converting portion for receiving said corresponding optical signal from said optical transmission channel, and for reconverting said corresponding optical signal into a second electrical signal;

a transmission channel for conveying said second electrical signal;

a branching portion for receiving said second electrical signal from said transmission channel, and for branching said second electrical signal into m branched elec-

trical signals, wherein  $m$  is a number greater than or equal to one and less than or equal to  $n$ ;

- a demodulating portion for receiving said  $m$  branched electrical signals, and for demodulating said  $m$  branched electrical signals to form  $m$  digital portion signals; and
- a hierarchy synthesizing portion for receiving said  $m$  digital portion signals, and for combining said  $m$  digital portion signals, such that a first to  $m$ th digital portion signals are arranged according to said decreasing degrees of importance from said highest degree to an  $m$ th degree according to said hierarchy, to form a synthesized digital signal which represents the information.

8. An optical transmission system as claimed in claim 7, further comprising:

- an analog-to-digital converting portion for receiving an analog information signal, converting the analog information signal into a digital information signal and for inputting the digital information signal into said hierarchy separating portion; and
- a digital-to-analog converting portion for receiving said synthesized digital signal from said hierarchy synthesizing portion and for converting said synthesized digital signal into a synthesized analog signal.

9. The optical transmission system of claim 7, wherein, in an entire transmission band of said electrical-optical converting portion, said optical transmission channel, said optical-electrical converting portion, and said transmission channel, a first of said  $n$  carriers, which carries a portion of the digital signal of a highest degree of importance, is arranged in a band, within the entire transmission band, having a transmission characteristic which is of high quality, and an  $n$ th of said  $n$  carriers, which carries a portion of the digital signal of a lowest degree of importance, is arranged in a band, within the entire transmission band, having a transmission characteristic which is of lower quality.

10. An optical transmission system comprising:

- a hierarchy separating portion for receiving a digital signal having  $w$  bits, and for dividing the digital signal into  $n$  digital portion signals each of which includes a respective one or more of said  $w$  bits, according to a hierarchy, such that a first to an  $n$ th digital portion signals are arranged according to decreasing degrees of significance of the respective one or more of said  $w$  bits, from a highest degree to an  $n$ th degree, wherein  $n$  is a number greater than or equal to two and  $w$  is a number greater than or equal to  $n$ ;
- a modulating portion for receiving said  $n$  digital portion signals, and for digitally modulating  $n$  carriers with said  $n$  digital portion signals respectively, to form  $n$  digital modulation signals respectively, said  $n$  carriers each having different frequencies;
- a multiplexing portion for receiving said  $n$  digital modulation signals, and for frequency multiplexing said  $n$  digital modulation signals to form a first electrical signal;
- an electrical-optical converting portion for receiving said first electrical signal, and for converting said first electrical signal into a corresponding optical signal;
- an optical transmission channel for conveying said corresponding optical signal;
- an optical-electrical converting portion for receiving said corresponding optical signal from said optical transmission channel, and for reconverting said corresponding optical signal into a second electrical signal;

a transmission channel for conveying said second electrical signal;

- a branching portion for receiving said second electrical signal from said transmission channel, and for branching said second electrical signal into  $m$  branched electrical signals, wherein  $m$  is a number greater than or equal to one and less than or equal to  $n$ ;
- a demodulating portion for receiving said  $m$  branched electrical signals, and for demodulating said  $m$  branched electrical signals to form  $m$  digital portion signals; and
- a hierarchy synthesizing portion for receiving said  $m$  digital portion signals, and for combining said  $m$  digital portion signals, such that a first to an  $m$ th digital portion signals are arranged according to said decreasing degrees of significance from said highest degree to an  $m$ th degree according to said hierarchy, to form a synthesized digital signal which represents the information;

wherein, in an entire transmission band of said electrical-optical converting portion, said optical transmission channel, said optical-electrical converting portion, and said transmission channel, a first of said  $n$  carriers, which carries a most significant bit of the digital signal, is arranged in a band, within the entire transmission band, having a transmission characteristic which is of high quality, and an  $n$ th of said  $n$  carriers, which carries a least significant bit of the digital signal, is arranged in a band, within the entire transmission band, having a transmission characteristic which is of lower quality.

11. An optical transmission system comprising:

- a hierarchy separating portion for receiving a digital signal which represents information, time/frequency converting said digital signal into a frequency digital signal, and for dividing the frequency digital signal into  $n$  digital portion signals each of which includes a respective one of a plurality of frequency components of the frequency digital signal, according to a hierarchy, such that a first to an  $n$ th digital portion signals are arranged according to decreasing degrees of importance of the respective frequency component, from a highest degree to an  $n$ th degree, wherein  $n$  is a number greater than or equal to two;
- a modulating portion for receiving said  $n$  digital portion signals, and for digitally modulating  $n$  carriers with said  $n$  digital portion signals respectively, to form  $n$  digital modulation signals respectively, said  $n$  carriers each having different frequencies;
- a multiplexing portion for receiving said  $n$  digital modulation signals, and for frequency multiplexing said  $n$  digital modulation signals to form a first electrical signal;
- an electrical-optical converting portion for receiving said first electrical signal, and for converting said first electrical signal into a corresponding optical signal;
- an optical transmission channel for conveying said corresponding optical signal;
- an optical-electrical converting portion for receiving said corresponding optical signal from said optical transmission channel, and for reconverting said corresponding optical signal into a second electrical signal;
- a transmission channel for conveying said second electrical signal;
- a branching portion for receiving said second electrical signal from said transmission channel, and for branch-

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- ing said second electrical signal into  $m$  branched electrical signals, wherein  $m$  is a number greater than or equal to one and less than or equal to  $n$ ;
- a demodulating portion for receiving said  $m$  branched electrical signals, and for demodulating said  $m$  branched electrical signals to form  $m$  digital portion signals; and
  - a hierarchy synthesizing portion for receiving said  $m$  digital portion signals, and for combining said  $m$  digital portion signals, such that a first to an  $m$ th digital portion signals are arranged according to said decreasing degrees of importance from said highest degree to an  $m$ th degree according to said hierarchy, to form a synthesized digital signal which represents the information;
- wherein, in an entire transmission band of said electrical-optical converting portion, said optical transmission channel, said optical-electrical converting portion, and said transmission channel, a first of said  $n$  carriers, which carries a lowest frequency component of the frequency digital signal, is arranged in a band, within the entire transmission band, having a transmission characteristic which is of high quality, and an  $n$ th of said  $n$  carriers, which carries a highest frequency component of the frequency digital signal, is arranged in a band, within the entire transmission band, having a transmission characteristic which is of lower quality.
12. An optical transmission system as claimed in claim 11, wherein said hierarchy separating portion time/frequency converts the digital signal by subjecting the digital signal to a Fourier transform.
13. An optical transmission system as claimed in claim 11, wherein said hierarchy separating portion time/frequency converts the digital signal by subjecting the digital signal to a discrete cosine transform.
14. An optical transmission system comprising:
- a hierarchy separating portion for receiving a digital signal which represents information, and for dividing the digital signal into  $n$  digital portion signals each of which includes a respective one of a plurality of portions of the digital signal, according to a hierarchy, such that a first to an  $n$ th digital portion signals are arranged according to decreasing degrees of importance of the respective portion, from a highest degree to an  $n$ th degree, wherein  $n$  is a number greater than or equal to two;
  - a modulating portion for receiving said  $n$  digital portion signals, and for digitally modulating  $n$  carriers with said  $n$  digital portion signals respectively, to form  $n$  digital modulation signals respectively, said  $n$  carriers each having different frequencies;
  - a multiplexing portion for receiving said  $n$  digital modulation signals, and for frequency multiplexing said  $n$  digital modulation signals to form a first electrical signal;
  - an electrical-optical converting portion for receiving said first electrical signal, and for converting said first electrical signal into a corresponding optical signal;
  - an optical transmission channel for conveying said corresponding optical signal;
  - an optical-electrical converting portion for receiving said corresponding optical signal from said optical transmission channel, and for reconvertng said corresponding optical signal into a second electrical signal;
  - a transmission channel for conveying said second electrical signal;

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- a branching portion for receiving said second electrical signal from said transmission channel, and for branching said second electrical signal into  $m$  branched electrical signals, wherein  $m$  is a number greater than or equal to one and less than or equal to  $n$ ;
  - a demodulating portion for receiving said  $m$  branched electrical signals, and for demodulating said  $m$  branched electrical signals to form  $m$  digital portion signals; and
  - a hierarchy synthesizing portion for receiving said  $m$  digital portion signals, and for combining said  $m$  digital portion signals, such that a first to an  $m$ th digital portion signals are arranged according to said decreasing degrees of importance from said highest degree to an  $m$ th degree according to said hierarchy, to form a synthesized digital signal which represents the information;
- wherein, in an entire transmission band of said electrical-optical converting portion, said optical transmission channel, said optical-electrical converting portion, and said transmission channel, a first of said  $n$  carriers, which carries a portion of the digital signal of a highest degree of importance, is arranged in a higher frequency band, within the entire transmission band, and an  $n$ th of said  $n$  carriers, which carries a portion of the digital signal of a lowest degree of importance, is arranged in a lower frequency band, within the entire transmission band.
15. An optical transmission system comprising:
- $p$  transmission sets for transmitting on  $p$  channels, each of said  $p$  transmission sets including,
    - a hierarchy separating portion, in said each of said  $p$  transmission sets, for receiving a digital signal from a corresponding one of said  $p$  channels, wherein the digital signal represents information, and for dividing the digital signal into  $n$  digital portion signals each of which includes a respective one of a plurality of portions of the digital signal, according to a hierarchy, such that a first to an  $n$ th digital portion signals are arranged according to decreasing degrees of importance of the respective portion, from a highest degree to an  $n$ th degree, wherein  $n$  is a number greater than or equal to two, and
    - a modulating portion, in said each of said  $p$  transmission sets, for receiving said  $n$  digital portion signals, and for digitally modulating  $n$  carriers with said  $n$  digital portion signals respectively, to form  $n$  digital modulation signals respectively, said  $n$  carriers each having different frequencies;
    - a multiplexing portion for receiving said  $n$  digital modulation signals from each of said  $p$  transmission sets, and for frequency multiplexing said  $n$  digital modulation signals from each of said  $p$  transmission sets to form a first electrical signal;
    - an electrical-optical converting portion for receiving said first electrical signal, and for converting said first electrical signal into a first optical signal;
    - an optical transmission channel for conveying said first optical signal;
    - an optical-electrical converting portion for receiving said first optical signal from said optical transmission channel, and for reconvertng said first optical signal into a second electrical signal;
    - a transmission channel for conveying said second electrical signal;
    - a branching portion for receiving said second electrical signal from said transmission channel, and for branch-

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ing said second electrical signal into m branched electrical signals, wherein m is a number greater than or equal to one and less than or equal to n; and

p electrical receiving sets, each of said p electrical receiving sets including,

- a demodulating portion, in said each of said p electrical receiving sets, for receiving said m branched electrical signals, and for demodulating, using carriers of a corresponding one of said p transmission sets, said m branched electrical signals to form m digital portion signals, and
- a hierarchy synthesizing portion, in said each of said p electrical receiving sets, for receiving said m digital portion signals, and for combining said m digital portion signals, such that a first to an mth digital portion signals are arranged according to said decreasing degrees of importance from said highest degree to an mth degree according to said hierarchy, to form a synthesized digital signal which represents the information of the digital signal from the corresponding one of said p channels.

16. An optical transmission system as claimed in claim 15, further comprising an entire transmission band, divided into first to nth information transmission bands which range from a low frequency band to a high frequency band respectively, wherein said first to nth information transmission bands include respective first to nth carriers from each of said p transmission sets.

17. An optical transmission system comprising:

- p transmission sets for transmitting on p channels, each of said p transmission sets including,
  - a hierarchy separating portion, in said each of said p transmission sets, for receiving a digital signal from a corresponding one of said p channels, wherein the digital signal represents information, and for dividing the digital signal into n digital portion signals each of which represents a respective one of a plurality of portions of the digital signal, according to a hierarchy, such that a first to an nth digital portion signals are arranged according to decreasing degrees of importance of the respective portion, from a highest degree to an nth degree, wherein n is a number greater than or equal to two, and
  - a modulating portion, in said each of said p transmission sets, for receiving said n digital portion signals, and for digitally modulating n carriers with said n digital portion signals respectively, to form n digital modulation signals respectively, said n carriers each having different frequencies;
  - a multiplexing portion for receiving said n digital modulation signals from each of said p transmission sets, and for frequency multiplexing said n digital modulation signals from each of said p transmission sets to form a first electrical signal;
  - an electrical-optical converting portion for receiving said first electrical signal, and for converting said first electrical signal into a corresponding optical signal;
  - an optical transmission channel for conveying said corresponding optical signal;
  - an optical branching portion arranged on said optical transmission channel for branching said corresponding optical signal into q optical signals, wherein q is a number greater than or equal to two; and
  - q optical receiving sets for receiving a respective one of said q optical signals, each of said q optical receiving sets including,

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- an optical-electrical converting portion, in said each of said q optical receiving sets, for receiving said respective one of said q optical signals from said optical branching portion, and for reconverting said respective one of said q optical signals into a second electrical signal,
- a transmission channel, in said each of said q optical receiving sets, for conveying said second electrical signal,
- a branching portion, in said each of said q optical receiving sets, for receiving said second electrical signal from said transmission channel, and for branching said second electrical signal into m branched electrical signals, wherein m is a number greater than or equal to one and less than or equal to n, and
- p electrical receiving sets, in said each of said q optical receiving sets, each of said p electrical receiving sets including,
  - a demodulating portion, in said each of said p electrical receiving sets, for receiving said m branched electrical signals, and for demodulating, using carriers of a corresponding one of said p transmission sets, said m branched electrical signals to form m digital portion signals, and
  - a hierarchy synthesizing portion, in said each of said p electrical receiving sets, for receiving said m digital portion signals, and for combining said m digital portion signals, such that a first to an mth digital portion signals are arranged according to said decreasing degrees of importance from said highest degree to an mth degree according to said hierarchy, to form a synthesized digital signal which represents the information of the digital signal from the corresponding one of said p channels.

18. An optical transmission system comprising:

- p transmission sets for transmitting on p channels, each of said p transmission sets including,
  - a hierarchy separating portion, in said each of said p transmission sets, for receiving a digital signal from a corresponding one of said p channels, wherein the digital signal represents information, and for dividing the digital signal into n digital portion signals each of which represents a respective one of a plurality of portions of the digital signal, according to a hierarchy, such that a first to an nth digital portion signals are arranged according to decreasing degrees of importance of the respective portion, from a highest degree to an nth degree, wherein n is a number greater than or equal to two, and
  - a modulating portion, in said each of said p transmission sets, for receiving said n digital portion signals, and for digitally modulating n carriers with said n digital portion signals respectively, to form n digital modulation signals respectively, said n carriers each having different frequencies;
  - a multiplexing portion for receiving said n digital modulation signals from each of said p transmission sets, and for frequency multiplexing said n digital modulation signals to form a first electrical signal;
  - an electrical-optical converting portion for receiving said first electrical signal, and for converting said first electrical signal into a corresponding optical signal;
  - an optical transmission channel for conveying said corresponding optical signal;
  - an optical-electrical converting portion for receiving said corresponding optical signal from said optical trans-

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mission channel, and for reconverting said corresponding optical signal into a second electrical signal;  
 an electrical distributing portion for receiving said second electrical signal and for branching said second electrical signal into  $t$  distributed electrical signals, wherein  $t$  is a number greater than or equal to two; and  
 $t$  branch receiving sets, each of said  $t$  branching sets including,  
 a transmission channel, in said each of said  $t$  branch receiving sets, for conveying a corresponding one of said  $t$  distributed electrical signals,  
 a branching portion, in said each of said  $t$  branch receiving sets, for receiving said corresponding distributed electrical signal from said transmission channel, and for branching said corresponding distributed electrical signal into  $m$  branched electrical signals, wherein  $m$  is a number greater than or equal to one and less than or equal to  $n$ , and  
 $p$  electrical receiving sets, in said each of said  $t$  branch receiving sets, each of said  $p$  electrical receiving sets including,  
 a demodulating portion, in said each of said  $p$  electrical receiving sets, for receiving said  $m$  branched electrical signals, and for demodulating said  $m$  branched electrical signals, using carriers of a corresponding one of said  $p$  transmission sets, to form  $m$  digital portion signals, and  
 a hierarchy synthesizing portion, in said each of said  $p$  electrical receiving sets, for receiving said  $m$  digital portion signals, and for combining said  $m$  digital portion signals, such that a first to an  $m$ th digital portion signals are arranged according to said decreasing degrees of importance from said highest degree to an  $m$ th degree according to said

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hierarchy, to form a synthesized digital signal which represents the information of the digital signal from the corresponding one of said  $p$  channels.

19. An optical transmission apparatus for transmission of information on an optical transmission channel, said apparatus comprising:

- a hierarchy separating portion for receiving a digital signal which represents information, and for dividing the digital signal into  $n$  digital portion signals each of which represents a respective one of a plurality of portions of the digital signal, according to a hierarchy, such that a first to an  $n$ th digital portion signals are arranged according to decreasing degrees of importance of the respective portion, from a highest degree to an  $n$ th degree, wherein  $n$  is a number greater than or equal to two;
- a modulating portion for receiving said  $n$  digital portion signals, and for digitally modulating  $n$  carriers with said  $n$  digital portion signals respectively to form  $n$  digital modulation signals respectively, said  $n$  carriers each having different frequencies;
- a multiplexing portion for receiving said  $n$  digital modulation signals, and for frequency multiplexing said  $n$  digital modulation signals to form an electrical signal; and
- an electrical-optical converting portion for receiving said electrical signal, for converting said electrical signal into a corresponding optical signal, and for outputting said corresponding optical signal onto the optical transmission channel.

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